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THESIS

COMPARATIVE ANALYSIS OF NESDI PROCESSES TO IMPROVE TECHNOLOGY INTEGRATION AT U.S. NAVAL FACILITIES

by

Kai Boon Eugene Mok

September 2018

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The mission of the Navy Environmental Sustainability Development to Integration (NESDI) program is to provide innovative solutions to reduce environmental-related risks, limitations, and costs while maintaining operational readiness. While NESDI has an established set of processes to develop the technology, techniques, and tools (TTT), it faces the challenge of integrating the TTT into naval facilities. To identify causes of the integration problem, this thesis conducts a comparative analysis of two completed NESDI projects with the systems engineering and innovation-decision processes. Findings from the comparative analyses are used to develop two frameworks. The first framework consists of the conduct of problem definition, needs analysis, and stakeholder analysis, while the second framework facilitates the integration of TTT into a naval facility. The author recommends the application of the frameworks as early as possible to existing NESDI and "new start" projects. Successful application of both frameworks will ensure an increased likelihood of technology integration at the enterprise or fleet level.

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COMPARATIVE ANALYSIS OF NESDI PROCESSES TO IMPROVE TECHNOLOGY INTEGRATION AT U.S. NAVAL FACILITIES

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ABSTRACT

The mission of the Navy Environmental Sustainability Development to Integration (NESDI) program is to provide innovative solutions to reduce environmental-related risks, limitations, and costs while maintaining operational readiness. While NESDI has an established set of processes to develop the technology, techniques, and tools (TTT), it faces the challenge of integrating the TTT into naval facilities. To identify causes of the integration problem, this thesis conducts a comparative analysis of two completed NESDI projects with the systems engineering and innovation-decision processes. Findings from the comparative analyses are used to develop two frameworks. The first framework consists of the conduct of problem definition, needs analysis, and stakeholder analysis, while the second framework facilitates the integration of TTT into a naval facility. The author recommends the application of the frameworks as early as possible to existing NESDI and "new start" projects. Successful application of both frameworks will ensure an increased likelihood of technology integration at the enterprise or fleet level.

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LIST OF ACRONYMS AND ABBREVIATIONS

AFFF	Aqueous Film Forming Foam
CCM	Compwater Collection and Management
DAU	Defense Acquisition University
DoD	Department of Defense
DOTMLPF	Doctrine, Organization, Training, Materiel, Leadership and Education, Personnel, and Facilities
EPA	Environmental Protection Agency
EXWC	Engineering and Expeditionary Warfare Center
IT	information technology
NAS	Naval Air Station
NAVAIR	Naval Air Systems Command
NAVFAC	Naval Facilities Engineering Command
NAVSEA	Naval Sea Systems Command
NAVSTA	naval station
NESDI	Navy Environmental Sustainability Development to Integration
NFESC	Naval Facilities Engineering Service Center
NFPA	National Fire Protection Association
PI	principal investigator
ppm	parts-per-million
PWD	Public Works Department
SE	systems engineering
SEBoK	Systems Engineering Body of Knowledge
SOP	standard operating procedures
SPAWAR	Space and Naval Warfare Systems Command
TDWG	Technology Development Working Group
TTT	technology, techniques and tools
WCF	Water Compensating Fuel

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EXECUTIVE SUMMARY

The Navy Environmental Sustainability Development to Integration (NESDI) is a program managed by the U.S. Naval Facilities Engineering Command (NAVFAC). The NESDI program serves to provide innovative solutions with technology, techniques, and tools (TTT) to naval facilities to “reduce operational environment risks, constraints, and cost while ensuring fleet readiness” (U.S. Navy Energy, Environment, and Climate Change n.d.-a). Despite the program’s efforts to integrate the developed TTT through various marketing means, it has achieved little success as the end users’ adoption of the technology is slow and the actual integration into naval facilities is extremely poor. As a result, most TTT projects have been shelved and the intended benefits were not realized.

The purpose of this study is to identify and review the factors that may impede technology integration when a systems engineering (SE) approach is not applied. Findings from the study are utilized to develop frameworks to guide NESDI’s future projects’ development so as to increase the likelihood of technology integration at naval facilities.

To steer NESDI’s TTT development effort based on the SE approach, the re-definition of “technology integration” is proposed. The new definition of technology integration entails a sequential process of technology transition, adoption, and diffusion:

- Technology transition refers to the process of putting the new TTT into use;
- Technology adoption refers to the moment when the end user accepts the new TTT in place of the existing TTT;
- Technology diffusion refers to the moment when there are two or more naval facilities adopting the new TTT.

Based on the new definition of technology integration, two comparative analyses are conducted using the logic of the comparative case studies approach (Yin 2014). An overview of comparative analyses conducted in this study is summarized in Figure 1.

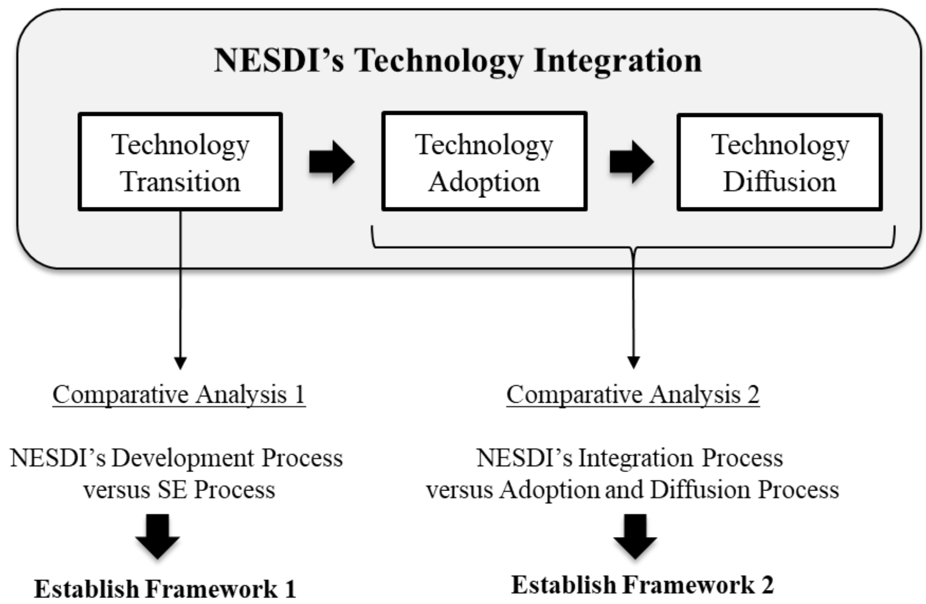

Figure 1. Overview of Comparative Analysis.

Prior to the conduct of the comparative analysis, an initial assessment of NESDI's current process is performed based on the 15 conditions of technology integration listed in NESDI's standard operating procedures (SOP) document (NAVFAC 2010). It reveals that the absence of need and stakeholder analyses might be the underlying reason limiting technology integration, as most projects did not reach the stage of implementing the integration process at the naval facility.

To verify the initial assessment, NESDI's *Project 341* (zinc removal from compensating ballast water, or compwater) is utilized to conduct the first comparative analysis with the SE process of problem definition, needs analysis, and stakeholder analysis. The purpose is to identify the effective need and key stakeholders for the project so as to increase the likelihood of technology integration. As part of the comparative analysis, it is found that only Naval Station (NAVSTA) Everett is identified as an affected port that required the zinc removal system to treat the high concentration of zinc impurities in the compwater produced by the Arleigh Burke class destroyers. Despite it being an effective need for NAVSTA Everett, the zinc removal system would have to be an enterprise-level need in order for it to be extended beyond NAVSTA Everett. Hence, additional NAVSTA are required to qualify the zinc removal system as an enterprise-level need. The comparative analysis suggested that additional NAVSTA such as the homeports and refueling ports where the Arleigh Burke class destroyer docks may well be the potential NAVSTA that require the zinc removal system. As such, key stakeholders from the potential NAVSTA, such as the commanding officers and the Naval Environmental Officer, should be engaged to solicit interest and support in developing the zinc removal system. To this end, the conduct of problem definition, needs analysis, and stakeholder analysis are essential to collect evidence to support the program as an effective need. In addition, involving the key stakeholders who recognize this as their NAVSTA's effective need in the development of the TTT would have a higher chance of getting the zinc removal system adopted by their end users. Based on these findings, Framework 1 (see Figure 2) is developed to provide NAVFAC and the NESDI program the foundation necessary to facilitate the development of the TTT and, more importantly, to increase the likelihood of successful technology integration across the U.S. Navy.

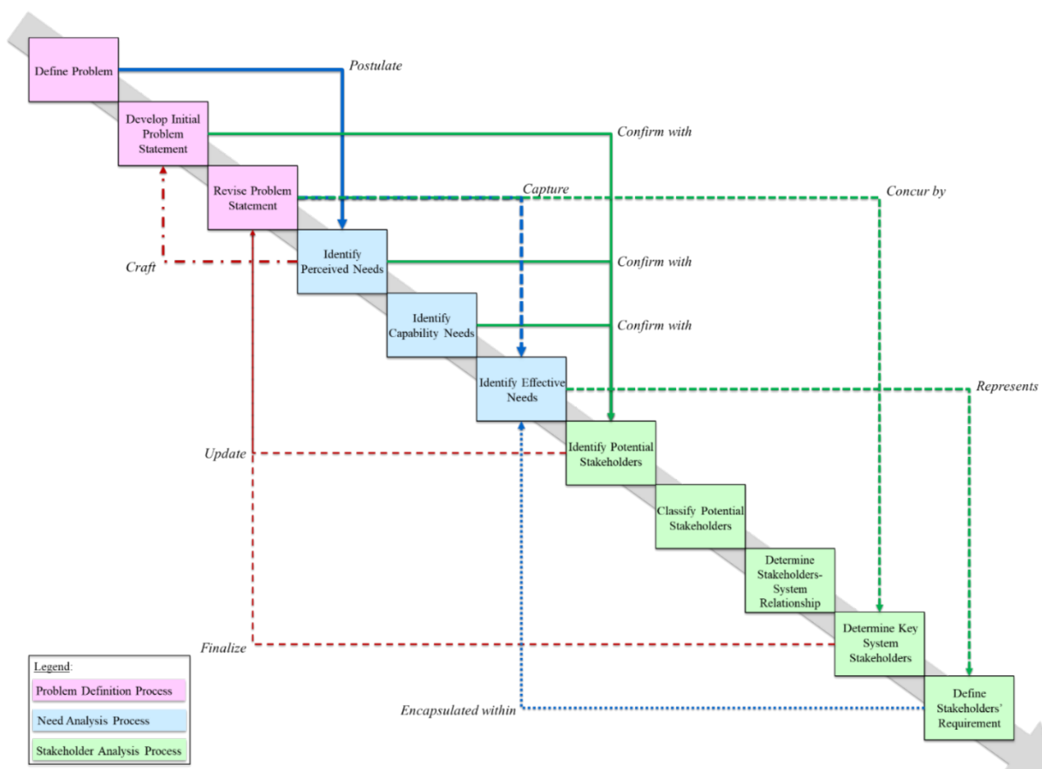

Figure 2. Framework 1.

The second comparative analysis is conducted between NESDI's integration process and the innovation-decision model (Rogers 1995). The purpose of this comparative analysis is to augment Framework 1 in providing the strategy to facilitate technology adoption and diffusion when the TTT is developed. With this, NESDI's *Project 288* (Nofoam system for automotive fire apparatus vehicle foam discharge checks, or Nofoam unit technology, for short) is utilized for this comparative analysis as it resulted in more than 200 automotive fire apparatus vehicles adopting the Nofoam unit technology across the U.S. Department of Defense (DoD). Extended beyond not only the Navy but across the DoD, the Nofoam unit technology program is considered to have achieved technology diffusion. Hence, findings from this comparative analysis can offer useful lessons.

The innovation-decision model begins with the end user when he/she is (1) aware about the new TTT (knowledge), (2) forms an attitude about the TTT (persuasion), (3) decides whether to incorporate the new TTT into ongoing practice (decision), (4) uses the TTT (implementation), and (5) recognizes the benefits of using the TTT (confirmation). After comparing to how the Nofoam unit is implemented, the findings are summarized in the Table 1.

Table 1. Comparative Analysis of Innovation Decision Process and Nofoam Unit Integration Process.

Innovation-Decision Process	Findings from Comparative Analysis of NESDI's Integration Process and Innovation-Decision Process
Knowledge stage	NESDI employed a series of advertising and marketing methods to increase the awareness for *Project 288* only toward the end of the development phase. It should, however, be done at the start of project development according to the SE process. Conducting stakeholder analysis (as part of Framework 1) will help to create initial awareness. The purpose of initial awareness is to obtain stakeholders' support in developing the TTT. As the TTT has an increased likelihood of being adopted by key stakeholders, credibility gained can further aid the TTT to circulate within and even beyond the enterprise.
Persuasion stage	To ensure end users replace the existing TTT with the new TTT, top-down command emphasis and an effective communication plan addressing the five perceived characteristics (relative

Innovation-Decision Process	Findings from Comparative Analysis of NESDI's Integration Process and Innovation-Decision Process
	advantage, compatibility, complexity, trialability, and observability) should be carried out.
Decision stage	Same as Persuasion stage, command emphasis on using the new TTT is encouraged. In addition, a feedback channel should be included to allow the end users to voice any concerns about and suggestions for the new TTT.
Implementation stage	Same as Knowledge stage, command emphasis during implementation of the new TTT is encouraged.
Confirmation stage	End users adopt the new TTT.

Based on the findings, Framework 2 (see Figure 3) is developed to (1) create awareness primarily at the earliest opportunity, (2) develop a communication plan to manage end users' expectations, (3) apply command emphasis to use the new TTT, and (4) establish a feedback channel. This will facilitate technology adoption and diffusion and subsequently increase the likelihood of technology integration at a naval facility.

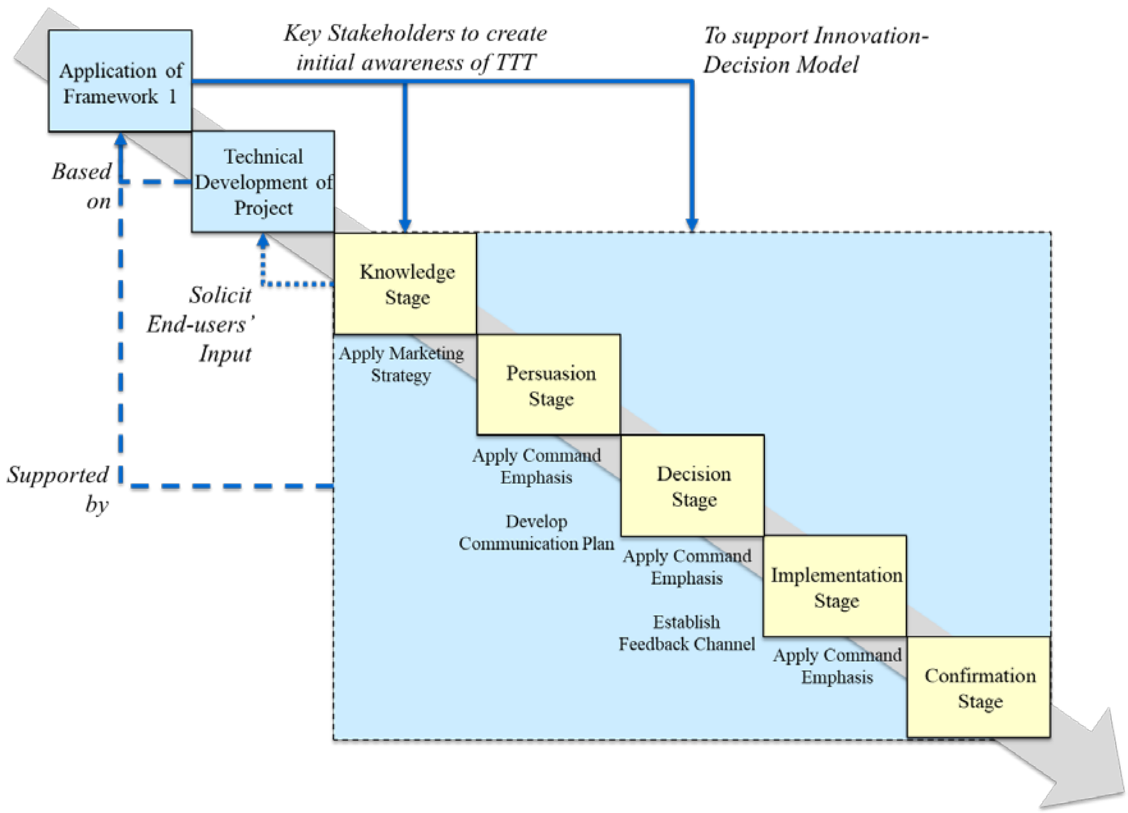

Figure 3. Framework 2.

In conclusion, Framework 1 essentially modifies NESDI's initial process to "collect, validate, and rank needs" (U.S. Navy Energy, Environment and Climate Change n.d.-b) to the SE approach of conducting of problem definition, needs analysis, and stakeholder analysis. The aim is to establish a firm foundation with key stakeholders' support to develop the TTT in accordance with the effective needs and requirements. Framework 2 essentially modifies NESDI's final process to "integrate solutions" (U.S. Navy Energy, Environment and Climate Change n.d.-b) by applying the innovation-decision model to create awareness, develop a communication plan, drive command emphasis, and establish feedback in facilitating the integration of new TTT.

Depending on the current phase of the project, applying the frameworks to existing and ongoing projects is recommended to make just-in-time correction. As the frameworks are meant to apply to "new start" projects, it is recommended to weave the SE and innovation-decision processes into the "new start" program schedule defined in the NESDI standard operating procedures (SOP) document.

Lastly, as this study only utilized two completed shore-based projects (*Project 341* and *Project 288*) in its comparative analyses, completed projects from other shore-based TTTs or other types of TTTs can be conducted to provide more inferences so that the frameworks can incorporate new lessons learnt and be revised accordingly. In addition, further studies can be proposed to evaluate the degree of success by measuring how well the TTT has been transitioned, adopted, and diffused in the U.S. Navy. Result from this study will reinforce the usefulness of the frameworks and provide a "tangible" form of benefit in using the frameworks.

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I. INTRODUCTION

A. PURPOSE

This research seeks to identify and review the factors that may impede the integration of a newly developed system or technology, techniques, and tools (TTTs) at a particular facility when a systems engineering (SE) approach is not applied. Two actionable frameworks are developed from the study's findings to serve as guidance for the Naval Facilities Engineering Command (NAVFAC) to pursue TTTs that can be integrated and extended fleet-wide. This study also offers a long-term definition of "integration" from which NAVFAC can draw alignment for its future projects. The synonyms for TTT used in this research include "system," "technology," and "innovation."

B. BACKGROUND

The Navy Environmental Sustainability Development to Integration (NESDI) is a program managed by NAVFAC, whose mission is to "provide solutions by demonstrating, validating, and integrating innovative technologies, processes, materials, and by filling knowledge gaps to minimize operational environmental risks, constraints, and costs while ensuring fleet readiness" (U.S. Navy Energy, Environment and Climate Change n.d.-a). While NESDI has an established set of processes to (1) collect, validate, and rank needs, (2) collect, evaluate, and rank proposals, (3) execute projects, and (4) integrate solutions (see Figure 1), it does not have a systematic framework that can provide guidance to ensure the successful integration of newly developed TTTs. As a result, most TTT projects have eventually been shelved, as the technology adoption of the newly developed TTTs by the end users is slow and the actual integration of such innovations into naval facilities is extremely poor. Hence, the intended benefits and projected cost savings could not be realized.

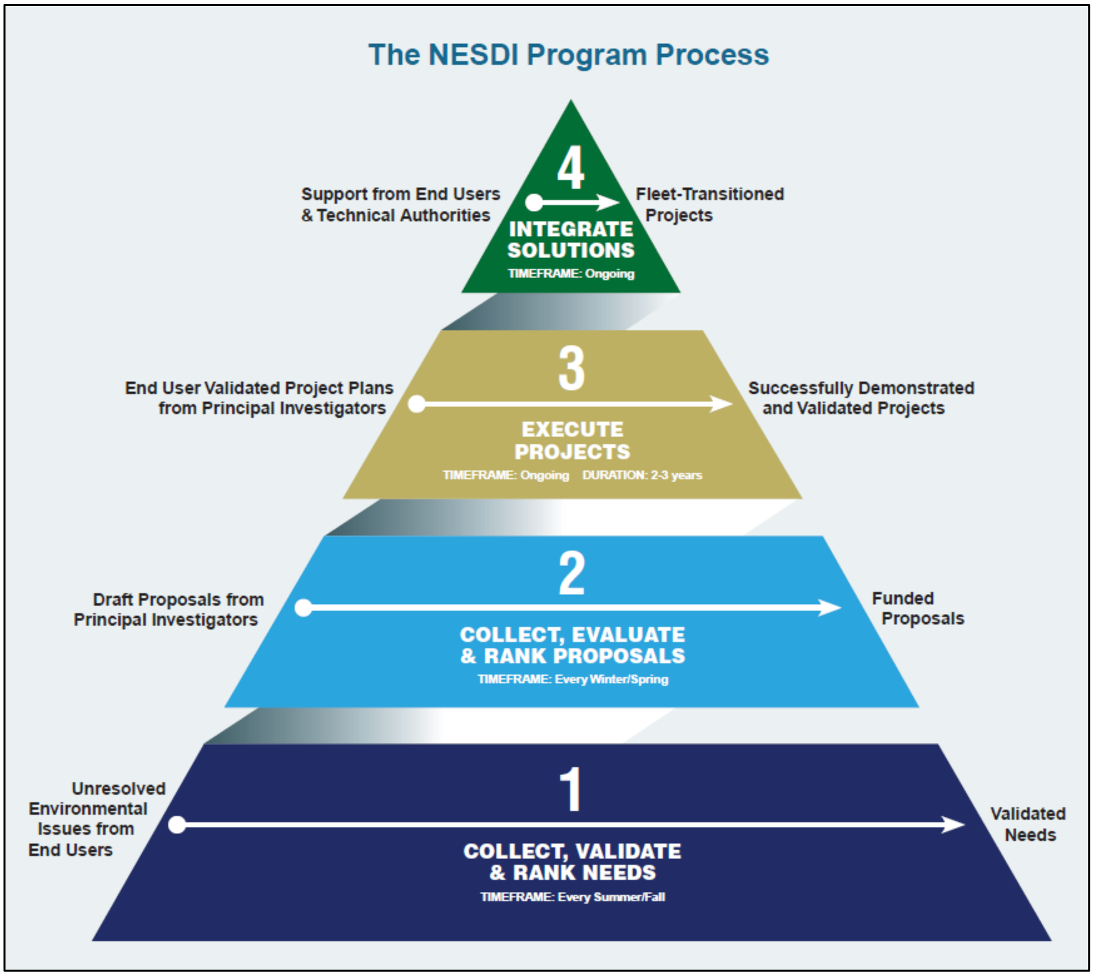

Figure 1. NESDI's Project Development Process. Source: NESDI (2016).

C. REDEFINING "INTEGRATION" FOR THE NESDI PROGRAM

The NESDI program's current and conventional approach of technology integration has focused largely on advertising with technical data and fact sheets, and seeking to sell the TTT as a package that presumably fits with every naval facility. According to NESDI's annual year in review report, fact sheets of active and completed projects are advertised through a variety of print materials (such as quarterly newsletters and *Current* articles, and the U.S. Navy's energy and environmental magazine) and online publications (http://navysustainability.dodlive.mil/environment/nesdi/), as part of an ongoing effort to promote the TTTs to potential stakeholders or clients. A more targeted approach that NESDI adopts is to contact a list of identified sites that would presumably benefit from the TTT. Information about the TTT is then disseminated to these sites to create awareness and generate conversation, with the aim of seeking their interest to buy into the TTT. While this approach reflects a genuine desire for integrating the TTT, it has omitted a holistic business plan and strategy required for effective TTT integration. Therefore, to steer NESDI's TTT development effort in the right direction, there is a need to redefine "integration."

The "integration" proposed for the NESDI program in this study consists of three phases: technology transition (phase I), technology adoption (phase II), and technology diffusion (phase III). The three phases represent NESDI's definition of integration from the moment the TTT is demonstrated and validated to the moment the TTT is extended to other naval facilities.

1. Technology Transition

Technology transition is the process of putting an innovation into use (Rogers 1995). In this regard, the technology transition process for the NESDI program begins as soon as the TTT has successfully been demonstrated and validated to meet the requirements derived from need and stakeholder analyses. The process of technology transition then carries on to the stage where the TTT is being installed at the naval facilities, accompanied by relevant enabling systems such as the provision of training, operating manuals, and maintenance capabilities. Throughout this process, there is long-term involvement between the developer of the technology and the intended end users. This partnership between the developer and the end users "drives an iterative process of technology development, implementation, and acceptance" (National Research Council 2004) by the user community that eventually leads to technology adoption and diffusion. In addition, the technology transition is also considered a collaborative process with stakeholders where the success of TTT integration is highly dependent on their participation and support (National Material Advisory Board 2004).

2. Technology Adoption

Technology adoption happens when the end-user accepts the new technology and uses it to replace the current technology (Rogers 1995). According to Everett M. Rogers, the rate at which the technology is adopted can be explained by five attributes: (1) relative advantage, (2) compatibility, (3) complexity, (4) trialability, and (5) observability (see Table 1). Hence, these attributes not only serve to help us measure the rate at which the TTT is adopted, but also to provide guidance in generating a tailored approach to implement the TTT at the naval facility.

Table 1. Attributes for Technology Adoption.

Attributes	Descriptions
Relative advantage	The extent to which an individual views a new TTT as a better option than the existing one.
Compatibility	The extent to which how an individual may use his/her existing experience to operate the new TTT.
Complexity	The extent to which the new TTT is easy to understand and learn to use shapes the intended user's views on the new TTT.
Trialability	The extent to which the TTT can be trialed. With more end users exposed to the new TTT during the trialing stage, the probability of TTT adoption when it is implemented increases.
Observability	The extent to which potential end users are aware of this TTT's benefits.

3. Technology Diffusion

Technology diffusion is the process by which the TTT is communicated and extended beyond the intended user to other naval facilities over time (Rogers 1995). It assumes the successful adoption of new TTT by the end users at the intended naval facility and thereafter continues to "disseminate" and diffuse the TTT to other naval facilities at the enterprise level, using various communication methods supported by the stakeholders. The TTT is considered to be "diffused" when two or more naval facilities adopt the TTT. Technology diffusion may be a challenging and time-consuming process, but effort must be made to achieve this goal. This study is an initial effort that aims to guide NAVFAC and the NESDI program in the right direction to increase the likelihood of successful technology integration at naval facilities.

D. SCOPE AND DELIVERABLES

The focus of this research is to examine and understand the process NAVFAC and the NESDI program currently adopt to develop, advance, and integrate new TTT into the naval facility. Using the comparative analysis approach, the current process for developing and integrating the TTT is compared with the SE process and the integration process (technology transition, adoption, and diffusion), respectively, to identify shortcomings with the current TTT development and integration process. The findings from the comparative analyses are used to establish frameworks to guide NAVFAC and the NESDI program, so as to increase the likelihood of successful technology integration for future TTTs.

E. BENEFITS OF THE STUDY

The actionable frameworks developed in this study can serve as guidance for the NAVFAC and the NESDI program to realign their work processes in accordance with the SE and integration processes. When the SE and integration frameworks are utilized effectively, the following benefits are envisaged:

1. Cost Savings and Higher Likelihood for Successful Integration

Once the effective needs and key stakeholders are identified, "half the battle is won," as the developed TTT will be highly supported by the key stakeholders who view the TTT as addressing their effective needs. In addition, it will also be in the key stakeholders' interest to get end users to adopt the new TTT. Therefore, with higher probability of technology adoption, the newly developed TTT can help the naval facilities involved to operate more effectively and efficiently, reaping the return on investment and cost-savings at the earliest possible opportunity.

2. Fundamental Changes in Work Processes

This study is expected to create awareness for the principal investigators (PI) in NAVFAC and possibly Naval Sea Systems Command (NAVSEA), Naval Air Systems Command (NAVAIR), and Space and Naval Warfare Systems Command (SPAWAR), if extended. If the developed frameworks are successfully adopted and diffused, it is expected to cause fundamental changes to the work processes in developing a new TTT. Command emphasis from upper management is recommended to drive and expedite this change.

F. OBJECTIVES

This study seeks to answer the following research questions:

1. How do the current NAVFAC and NESDI integration processes compare to the systems engineering integration process?

2. How do NAVFAC and NESDI define integration and successful integration?

3. What are the challenges that NESDI encounters during the integration of a new TTT?

4. What means do NAVFAC and NESDI provide to the end users during the course of TTT integration (i.e., subject matter expert training, just-in-time training, on-site assistance, feedback.)?

5. How can the current NAVFAC and NESDI integration process be modified to increase the likelihood of success?

G. ORGANIZATION

This thesis consists of five chapters. The remaining chapters are structured in the following manner. Chapter II is a literature review highlighting common barriers to integration and accepted principles of integration in and out of the systems engineering domain. Chapter III contains the research methodology that states the strategy to address the research questions and outlines how comparative analyses between the SE process and the select number of NESDI cases (completed projects) are done. Chapter IV analyzes and presents the results from this work. Findings from the analyses are used to develop the framework for the NESDI program to screen future projects. Lastly, the Chapter V concludes with recommendation for future work.

II. LITERATURE REVIEW

A. INTRODUCTION

Innovation is the introduction of new techniques, technologies, or tools that improve the current way of how work is done. From an organizational perspective, innovation aims to maximize cost savings, improve efficiency, and enhance quality of service. To achieve the envisaged benefits, the TTT projects developed by the NESDI program need to be integrated into naval facilities. The motivation of this study is to understand the factors that hamper NESDI projects integrating into targeted naval facilities.

B. BARRIERS TO TECHNOLOGY INTEGRATION

Many barriers can hinder technology integration. Six types of barriers to technology integration are identified to give the reader an understanding of how such barriers may potentially impact successful TTT integration.

1. Organization Objectives Not Aligned for Technology Integration

Studies have shown that for technology to be integrated, the adopting organization's objectives must be aligned for this purpose (Elmorshidy 2013). Aligning the objectives of developing any TTT with NESDI's integration strategy is considered as one of the most crucial survival and success factors for technology integration. As evident in the information technology (IT) industry, Joseph W. Weiss and Don Anderson (2004) highlighted in their study that the consequences of failing to align an organization's objectives with technology integration results in the following mishaps:

- Inability to invest the company's finance in a way that can create the opportunity for investment and funding.
- Inability to gain trust with the business and provide proactive rather than reactive services.
- Inability to attract and retain appropriate skills.

- Inability to measure IT's contribution to the business in terms of technology adoption and return on investment.

- Inability to communicate strategy to employees and link strategy to budgets (Weiss and Anderson 2004, 2).

2. Incomplete or Wrong Set of Stakeholders

Identifying the correct and key stakeholders plays an important role to ensure that the technology is developed in accordance to their effective needs and subsequently translated to a specific set of stakeholder requirements. According to the SE Body of Knowledge (SEBoK), stakeholder requirements (1) form the foundation for the system requirements, (2) act as a basis for system validation and stakeholder acceptance, (3) serve as a reference for verification, and (4) provide a means of communication between the developer, technical staffs, and all related personnel (SEBok 2017). Therefore, when key stakeholders are not identified or involved in the initial planning stage of development, technology integration at the intended organization or naval facility is not possible.

3. Addressing a Wrong Need

A viable innovative idea generally starts by identifying a "want" or "desire." This is considered the "perceived need." Undergoing a needs analysis as part of the systems engineering process will translate the "perceived needs" to an effective or a true need. Need analysis is often conducted together with stakeholder analysis to determine the effective needs so that the envisaged technology developed meets the stated requirements. When the Google Glass was first introduced in 2012, it did not last long in the consumer market due to many criticisms. Such criticisms focused on the poor design and lack of aesthetic appeal, exorbitant pricing, and its slow development that never seemed to bring the product out of the beta (trial) stage. The main reason why Google Glass is considered a failure, however, stems from its lack of connection with real consumer needs. The "perceived" need to (1) quickly capture images and (2) have the ability to access the internet at a "glance," which in this case, is not a true need consumers are looking for (Doyle 2016). In the same light, the approach of developing this innovative technology first and seeking buy-ins from interested users later may not have been an appropriate way to market the product (Marks 2014). This explains why Google Glass failed. The importance of performing needs analysis to identify the consumer's true need is necessary to render the product a successful one.

4. Lack of Resources

Resources such as time, manpower, budget, and technical support are required to promulgate new technology. Lacking any of these resources may impede or even hinder technology integration. This is prevalent in the education industry where technologies are highly utilized to deliver educational content. The lack of budget to procure advanced educational tools, to implement the use of specific tools across schools, and to provide technical support has resulted in a lack of technology integration (Tarleton State University n.d.). In addition, insufficient time dedicated to integrating technology into the teaching syllabus and the lack of support have forced educators to spend out-of-office time to review and get familiar with new technology. This eventually leads to teacher "burn out," and may even cause teachers to leave the organization (Conley 2010).

5. Regulatory Restrictions

Regulatory restrictions from the government may also be a reason why technology cannot be integrated. One classic example is the invention of the modern car in the late 1800s. Although the modern car was first invented in Britain, it was actually commercialized in the United States. This was because the government of England enacted *The Red Flag* act due to safety concerns. This act required at least three persons to operate the vehicle such that one would drive the vehicle, one would fill the gas, and one would wave a red flag. Limited by this act, the commercialization of modern cars shifted to the United States, and the rest is history (Khanna 2015). On the same note, technology integration may be restricted by the obsolescence of government regulations, which frequently lack the agility to catch up with the latest innovative solutions. To this end, little or nothing can be done to influence the government regulatory authority from the developer's perspective.

6. Adoption and Diffusion Barriers

Technology adoption happens when the end user accepts the new technology as a replacement for the current technology, and diffusion occurs subsequently, when even more end users, in this case, from other naval facilities begin to adopt the new technology due to its well-known benefits (Rogers 1995). One of the main reasons that could prevent technology adoption and diffusion is the trade-off between the cost and benefits of a new TTT. When a developed technology is commercialized, potential customers from various organizations may be most interested in the cost and benefits of the new technology. Knowing the cost and benefits of new technology will help them to decide whether it is financially viable to own and operate with the new technology. When solar technology was first introduced, for example, it quickly became popular, as it is known to provide green energy with low energy price. Nevertheless, the high investment cost and a failure to account for the public energy and environmental benefits became the main barrier in getting the technology quickly adopted and diffused (Philibert 2006) as potential buyers were unwilling to take the risk without substantiated data.

C. PRINCIPLES OF INTEGRATION

This section explores four relevant guiding principles derived by Gary Langford (2012) after he reviewed many case studies on integration failures. These guiding principles can also be regarded as baselines from which the NESDI program can draw alignment when developing a TTT (Langford 2012, 11–24).

1. The Principle of Alignment

> Alignment of strategies for the business enterprise, the key stakeholders, and the project results in better outcomes for product or service development.
>
> —Langford (2012, 11)

Understanding the effective needs of the key stakeholders and knowing how they are supported by the organization’s strategic directions (i.e., mission, vision, and goals) are important. Any misalignment between the organization’s objective and the business enterprise creates a barrier to technology integration. For successful integration of technology, Langford (2012) has suggested that the strategies between the key stakeholders needs should be aligned with the project goals and the delivery of the agreed upon product, service, or tools. This ensures that the functional and performance requirements of the technology are delivered within the budget and time constraints.

From the SE standpoint, this principle corresponds to the importance of performing a thorough problem definition that addresses the stakeholders' true needs. When the stakeholders' vital inputs are taken into consideration in crafting and refining the problem statement, it would also have encompassed the stakeholders' objectives (which are aligned to their business enterprise) in getting the technology integrated within their organization.

2. The Principle of Induction

> Inductive reasoning should guide integration management and recursive thinking.
>
> —Langford (2012, 11)

The central idea of this principle is to forecast technology integration events based on preceding events. As Langford (2012) explained, induction refers to deducible methodology that can facilitate understanding given the uncertainty. Since systems engineering and the system integration process are considered to be broadly iterative, using a systematic approach for the development of a project can be useful. To achieve successful integration, a recursive system thinking process should also be adopted due to the iterative nature of systems engineering. Adapted from the Defense Acquisition University under the U.S. Department of Defense (DoD), Figure 2 is a condensed version of the SE process in a top-down iterative manner. By performing requirements analysis, functional analysis, and the synthesis step as part of an iterative process, one should be able to anticipate how the deliverables achieved in the current step apply to the next step recursively. In doing so, every step performed will be meaningful in obtaining a more refined result using the data and information gained from the preceding step. The principle of induction or recursive thinking should be applied to any iterative processes in the course of developing new TTTs.

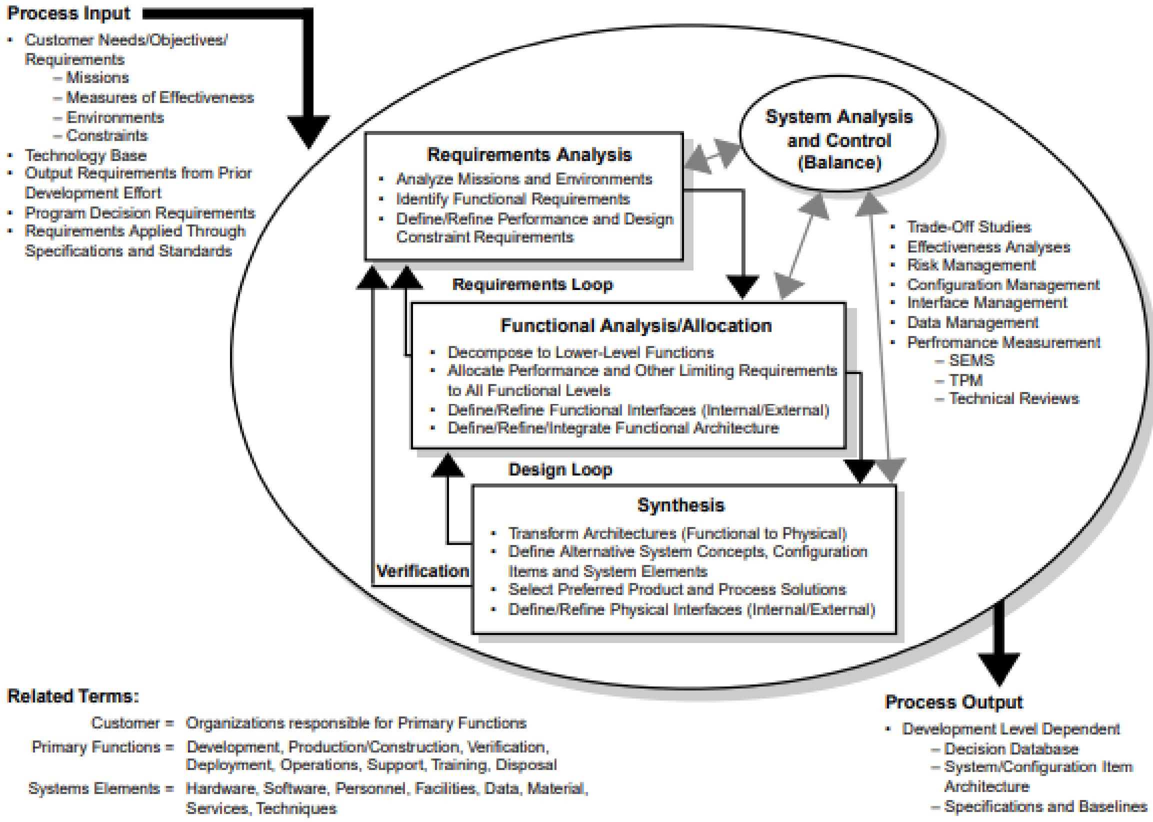

Figure 2. The Systems Engineering Process. Source: DoD (2001).

3. The Principle of Limitation

Integration is only as good as architecture captures stakeholder requirements.

—Langford (2012, 15)

The purpose of system architecture is to propose a complete and extensive solution to a well-defined problem based on a set of guiding principles and concepts that are logically related and consistent with one another (SEBoK 2017). As Langford (2012) puts it, the architecture used for the development of the technology shall "represent the key stakeholder needs and requirement as modified by their values, preferences, and desires." Therefore, the system architecture for a well-defined effective need from the stakeholders is essential for its integration. From the SE standpoint, this principle corresponds to the importance of conducting needs and stakeholder analyses. Capturing the stakeholder effective or true need and their requirements sets the foundation for further development.

4. The Principle of Forethought

> Integration is a primary, key activity, not an afterthought considered as a result of development.
>
> —Langford (2012, 11)

Planning for technology integration should be deliberate and should not be treated as a "by-product" or a process that "happens naturally" during implementation. Hence, integration of new technology within an organization must be deliberately planned. In fact, Langford (2012) has stressed that planning for integration should start as early as the initial development phase so as to facilitate the planning of developmental tasks. Other factors such as culture, skills, and the working style of the project team can also be considered when planning for any teamwork. This principle of forethought may be applicable to the NESDI program as the integration of a TTT is only performed toward the end of the project phase, thus limiting the success of integration at naval facilities.

D. INDUSTRY EFFORTS TO INCREASE TECHNOLOGY INTEGRATION

This section of the literature review considers previous efforts to improve technology integration in different industry sectors. An understanding of how different industries view technology integration and the level of effort and what planning is required to ensure technology integration provides a baseline against which NESDI can measure their own efforts. These examples from industry will help this research to develop ways to improve technology integration for NESDI projects.

1. Technology Integration Efforts in the Education Sector

The use of technological platforms to facilitate teaching and learning is common in the education industry sector. Most educational technologies are designed with the aim of making learning fun and meaningful, especially at the kindergarten to 12th grade (K–12) level. The effort to increase the use of technology in the education sector has hence been widely studied. A study on such technology integration in developing countries showed effective integration of new technology in schools required (1) strategic planning to ensure the use of the technology is aligned with the vision, goals, and objectives of the institution, (2) management planning to allocate budget for the development and acquisition of educational tools, as well as (3) operational planning to determine the training and staffing needs, and an action plan for implementing the technology within an institution (Jhurree 2005). Operational planning, in particular, is considered to be the most important as it "executes" the plan to the end users. Planning for technology integration for the NESDI program is similar, where strategic and management planning sets the direction and operational planning carries out the plan. In this regard, developing frameworks to guide the NESDI program is part of an operational task to increase the likelihood of successful technology integration for future TTTs.

2. Technology Integration Effort in the Health Care Sector

Health care operations depend heavily on information technology (IT). The use of IT in the health care industry essentially consists of three main categories: (1) infrastructure (i.e., electronic health records), (2) performance enhancement (i.e., computer-based clinical decision support systems), and (3) performance evaluation (i.e., measurement of the cost, effectiveness, and outcomes of different systems) (Doebbeling et al. 2006). According to Bradley Doebbeling et al., the effort to integrating IT successfully into the health care industry mainly focuses on the social engineering aspect, especially at the system level. In addition, having an open culture in the workplace where workers are encouraged to provide feedback is an important and useful way to ensure that IT can be better integrated into the health care industry (Doebbeling et al. 2006). In this regard, the effort to carry out technology integration at a naval facility must consist of effective communication to keep the end users well informed of the TTTs' development. Feedback channels should also be established as early as possible for end users to provide inputs and address potential concerns that might be crucial to the development of the TTT.

III. METHODOLOGY

> If I were given an hour in which to do a problem upon which my life depended, I would spend 40 minutes studying it, 15 minutes reviewing it, and 5 minutes solving it.
>
> —Albert Einstein

A. OVERVIEW

The preceding quotation from Einstein emphasizes the importance of understanding a problem prior to solving it. The initial phase of the SE process mirrors Einstein’s point. The process of understanding the problem is encapsulated within the conceptual design phase of the SE process where problem definition, needs analysis, and stakeholder analysis are conducted to establish the system requirements needed for further development (see Figure 3). This phase of the SE process is central to how this study addresses the thesis objectives.

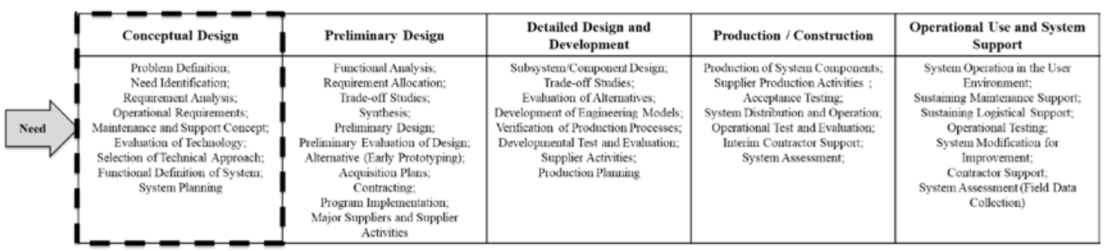

Figure 3. System Process Activities and Interactions throughout the System Life Cycle. Source: Blanchard and Fabrycky (2011).

Setting a strong foundation by identifying the true need and the key stakeholders is instrumental in paving the way for successful technology integration. The key stakeholders have a vested interest in getting the newly developed TTT diffused to several (if not all) naval facilities if the TTT has achieved the established system requirements, thereby allowing the naval enterprise to reap the projected benefits (i.e., work efficiency and cost savings).

B. FRAMEWORK TO CONDUCT COMPARATIVE ANALYSIS

To conduct a comparative analysis between the NESDI's current processes and the proposed processes in this study, we apply the logic of a comparative case studies approach (Yin 2014). This five-step approach is summarized in Figure 4. The purpose of conducting a comparative analysis is to identify and highlight the differences and gaps between the processes. Findings from the comparative analyses are then used to develop frameworks to guide the NESDI program in future TTT development so as to increase the likelihood of successful technology integration at naval facilities.

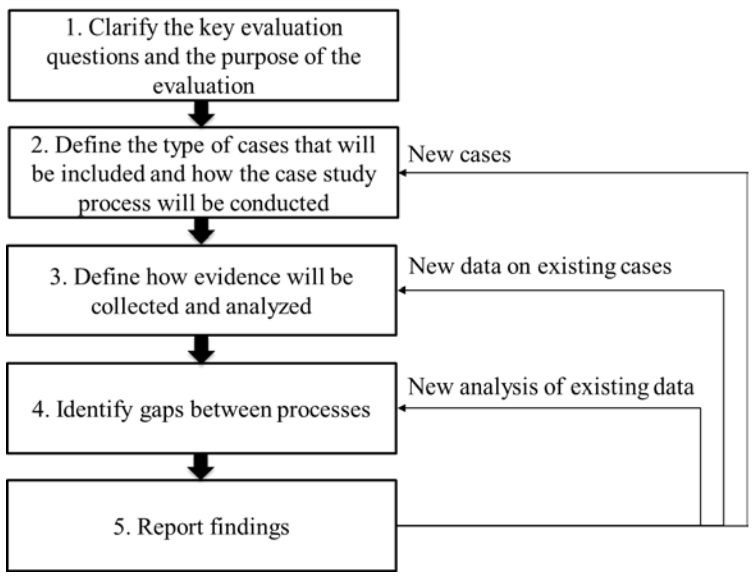

Figure 4. Logic of Comparative Case Studies. Source: Yin (2014).

1. Clarify the Key Evaluation Questions and the Purpose of the Evaluation

The first step in the logic of the comparative case studies approach is to ask key evaluation questions (KEQ) or high-level questions to rationalize the use of comparative analysis as a basis for the evaluation of processes. Some questions related to process evaluation are:

- How appropriate is the NESDI’s TTT development process as compared to the SE process?

- How appropriate is the NESDI’s integration process as compared to the newly defined integration process proposed in this study?

- How satisfied are the stakeholders?

2. Define the Types of Cases Used and How Comparative Analysis Will Be Conducted

We use two completed NESDI projects as case studies for the comparative analyses. We compare one case with the SE process and another case to examine the adoption and diffusion process. Details of the comparative analyses for the two case studies are elaborated in Chapter IV.

3. Define How Evidence Will Be Collected and Analyzed

The author visited the NAVFAC Engineering and Expeditionary Warfare Center (EXWC) in Port Hueneme in April 2018, and spoke with various key appointment holders. Information and data collected during the visit are used to facilitate the conduct of the comparative analyses between the processes. Comparative analysis is an iterative process. Whenever there are new data on existing cases, new analysis and in-depth interpretation can provide new insights or additional evidence to address potential gaps in the current NESDI integration process.

4. Identify Gaps between Processes

Gaps and differences identified in the preceding steps are used to formulate a framework, which in turn can be used increase the likelihood of successful integration of TTTs. This is also an iterative process whenever new analyses of data can help identify additional gaps that can be leveraged to improve the framework.

5. Report Findings and Develop Framework

Results yielded from the comparative analysis are used to develop the framework for the NESDI program.

C. COMPARATIVE ANALYSES OF PROCESSES

In Chapter I, the definition of technology integration is redefined for the NESDI program to establish a common understanding. Using this new definition, meaningful comparative analyses can be established at different stages of the technology integration process to identify the gaps and differences between the processes (see Figure 5). Initial assessment of the NESDI's process is evaluated to identify the potential root causes that limit technology integration. Next, using two completed projects from the NESDI program, comparative analyses are conducted with the SE process and the adoption and diffusion (innovation-decision) process to validate the initial assessment and identify gaps between the processes. Lastly, findings from the previous section are utilized to develop the frameworks to provide detailed guidance for NAVFAC and the NESDI program in developing future TTT projects.

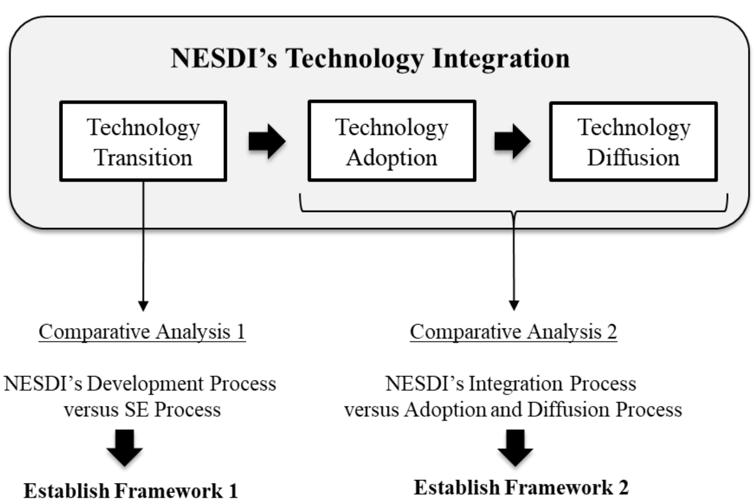

Figure 5. An Overview of Comparative Analyses.

1. Comparative Analysis of NESDI's Development Process Versus SE Process

To facilitate technology transition, the TTT development process must be built on the right foundation. The focus of the first comparative analysis is to set the groundwork by comparing the NESDI's development process and the SE process. Adapted from the *NESDI 2016 Year in Review Report*, the NESDI program process or the TTT development process is summarized into four broad steps as depicted in Figures 1 and 6. The SE process, on the other hand, is adapted from the DoD SE Process Model of 2014 where the process of developing a defense capability is summarized in a Vee model. In this comparison, emphasis is given to the initial development process where (1) problem definition, (2) needs analysis, and (3) stakeholder analysis are conducted (shaded region of Figure 6). This is important as the basis of this comparative analysis is to establish a valid foundation for system development first. The process of conducting problem definition, needs analysis, and stakeholder analysis are described in the following sub-sections. These SE processes are followed closely to draw comparisons with the NESDI approach of integrating *Project 341* (zinc removal from compensating ballast water) into the U.S. Navy enterprise.

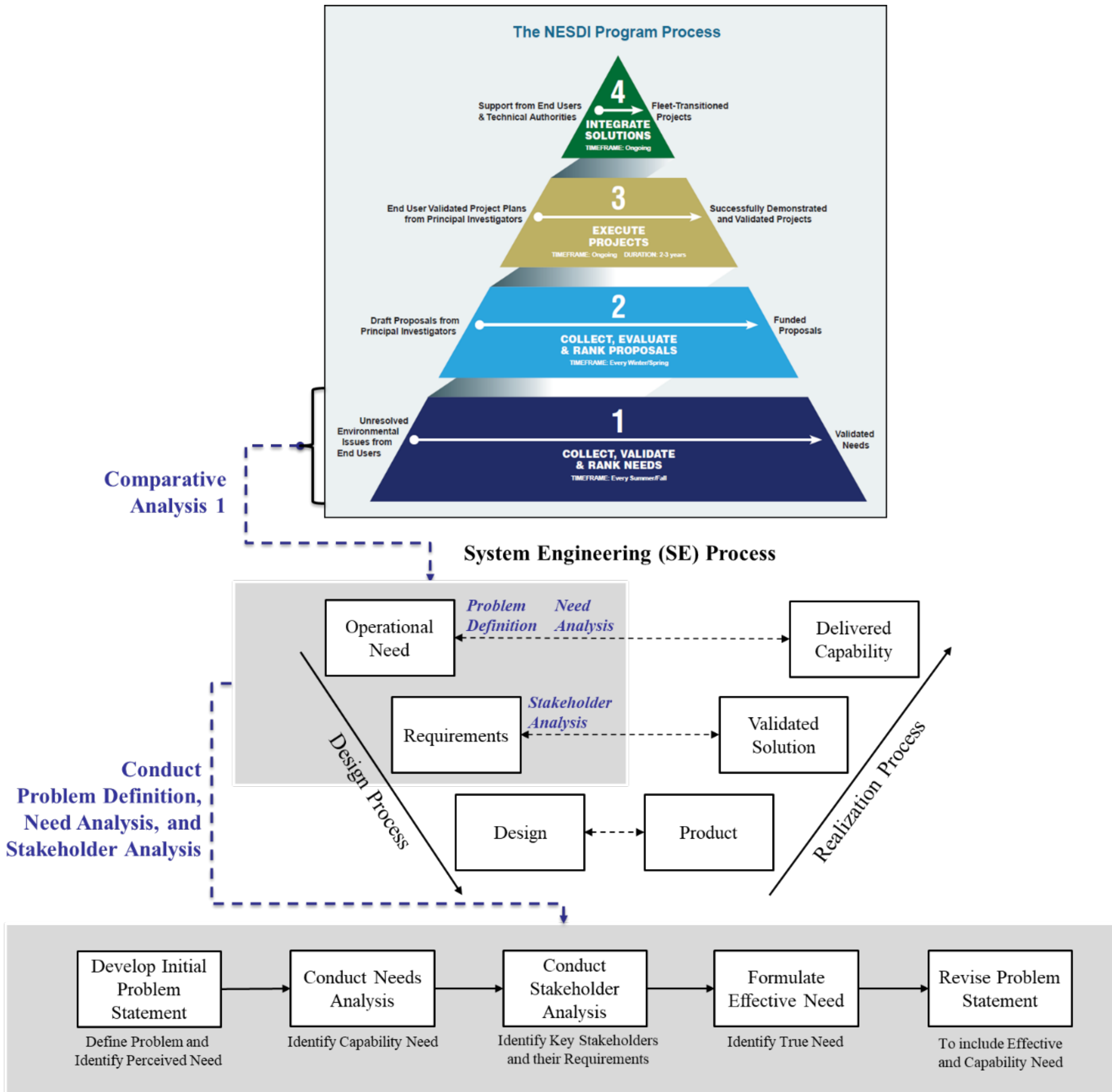

Figure 6. Comparative Analysis of NESDI's Development Process and the SE Process. Adapted from NESDI (2016).

a. Problem Definition

To begin identifying a need, we must first define the problem at hand. The initial problem statement establishes the perceived needs. Information and knowledge realized later during the needs and stakeholder analyses will be utilized to refine the problem statement. This frames the problem more accurately for the development of the TTT. The initial problem definition can be crafted by answering the following questions (Holness 2017):

- When did the problem arise?
- What had been done with the problem before?
- What would the world be like if the problem did not exist?
- Do we have all the facts or supporting evidence? Are they accurate?
- Is there a logical explanation for the cause of the problem?

On the similar note, SEBoK also raises the following questions to further clarify the problem (SEBoK 2014):

- Does everyone think that it is a problem?
- Who or what is impacted?
- What is the environment and what are the external factors that affect the problem?

There are many methods to define the problem. Observation, surveys, and interviews are just some of the techniques to define the problem. Alternatively, other popular methods, such as the *Five why's Technique*, *casual loop diagram*, or the *Ishikawa (fishbone) diagram*, can also be used to frame and give clarity to the problem (Blanchard and Fabrycky 2011). These methods facilitate the identification of the potential cause of the problem and could eventually lead to the root cause. Knowing the root cause thus helps to frame the problem area better. Having an accurate problem statement is important to increasing the likelihood of successful technology integration because it helps the development team and the key stakeholders to stay focused and establish a common understanding of the problem at hand.

b. Needs Analysis

Needs analysis is an iterative process that generally starts by establishing an initial problem statement where the perceived needs from the stakeholders, clients, or the decision makers are captured. The problem statement is then revised iteratively to include new information or knowledge that helps to refine the problem. Once the initial problem statement is crafted, asking the following questions helps to establish some key "parameters" that are essential to identify a true, actual, or effective need. The following questions are proposed to help guide the identification of an effective need (Holness 2017):

- What is the situation? Is it a new development or an improvement type of project?
- What kind of need is the system/TTT fulfilling?
- Is there any relationship with other needs?
- What is the frequency of the need?
- How urgent is the need?
- What limits are imposed on the solution set?
- What are the potential impacts in the environment and on other systems?
- Are there tolerances to be observed when satisfying the need?
- What are the viewpoints of the stakeholders?

Identifying the effective need is crucial to achieving successful technology integration because it directs the development of the TTT and solves the problem experienced by various naval facilities at the enterprise level. This enables the U.S. Navy to advance in accordance with the strategic direction set by the NESDI program—that is, to "minimize operational environmental risks, constraints, and costs while ensuring fleet readiness" (U.S. Navy Energy, Environment and Climate Change n.d.-a). While the current TTTs developed by the NESDI program address an impending need, it is still required to ensure that the impending need is an effective need at the enterprise level. Meeting the effective need with a specifically designed TTT will promote technology integration across the U.S. Navy.

c. Stakeholder Analysis

The stakeholder is considered to be the "individual or organization having a right, share, or interest in a system or in its possession of characteristics that meet their needs and expectations" (ISO/IEC/IEEE 2015). Hence, identifying and analyzing the stakeholder needs is considered stakeholder analysis. Langford's book on engineering systems integration is extensively referenced for stakeholder analysis as he provides detailed and systematic guidance for analyzing qualitative information to determine the interests of stakeholders when developing a TTT (Langford 2012, 259–265). This study adopts Langford's five-step approach in conducting stakeholder analysis.

(1) Identify of Potential Stakeholders

There are many ways to identify potential stakeholders. One of the simplest ways is to conduct a brainstorming session with a project team and list any customers or users who may have an interest in the proposed TTT and how it can potentially benefit them in the long run. In this regard, the Defense Acquisition University (DAU) has provided some useful questions that may help to identify potential stakeholders. The list of questions is by no means exhaustive (DAU 2017):

- Who will receive the deliverables of or benefits from the proposed TTT?
- Who will work with you to implement the project?
- Who is paying for the project?

(2) Classify Potential Stakeholders

After identifying the list of potential stakeholders, the next step is to classify them into internal, first-, and second-order stakeholders. (Langford 2012):

(i) Classify Potential Internal Stakeholders

Langford defined potential internal stakeholders as those who "only interact with internal system elements or with other stakeholders" (Langford 2012, 262). They are the ones with the largest stake in the project and are responsible for the development and integration of the TTT.

(ii) Classify Potential First- and Second-Order Stakeholders

Langford defined potential first-order stakeholders as those who “have direct contact with the system but do not have direct interactions with the internal stakeholders” (Langford 2012, 262). By contrast, the potential second-order stakeholders are those who “are connected indirectly to the system via the interaction with first-order stakeholders” (Langford 2012, 262).

(3) Determine Potential Stakeholder-System Relationships

Once the potential stakeholders are identified, the next step is to prioritize them based on how the potential stakeholders may influence the system. The purpose of doing so ensures that the vital inputs and feedback provided by the stakeholders are taken into consideration for subsequent development (Langford 2012, 262). The following questions can be used as a guide to determine how much influence a stakeholder may have (DAU 2017):

- What legitimate authority do the stakeholders have in the organization (i.e., do they control the budget?)

- Who controls the strategic resources for the project?

- How much negotiation power or influence do particular stakeholders have over others?

In conjunction with stakeholders’ influence, we can also represent the priority of the potential stakeholders in a graphical way using the Power-Interest Matrix (Mendelow 1991). By answering the following question, the identified stakeholders can be prioritized into one of the four quadrants of the Power-Interest Matrix (see Figure 7). Therefore, this forms the stakeholder management strategy to promote positive relationships during the course of project development and minimize negative impacts on the stakeholders. Some questions to guide the prioritization of potential key stakeholders include:

- What is the power of the stakeholders (power and interest)?
- How much influence do they have on the project (power and influence)?
- What is the interest level of the stakeholders (influence and impact)?
- How much do they desire to be involved with the project (power, urgency, and legitimacy)?

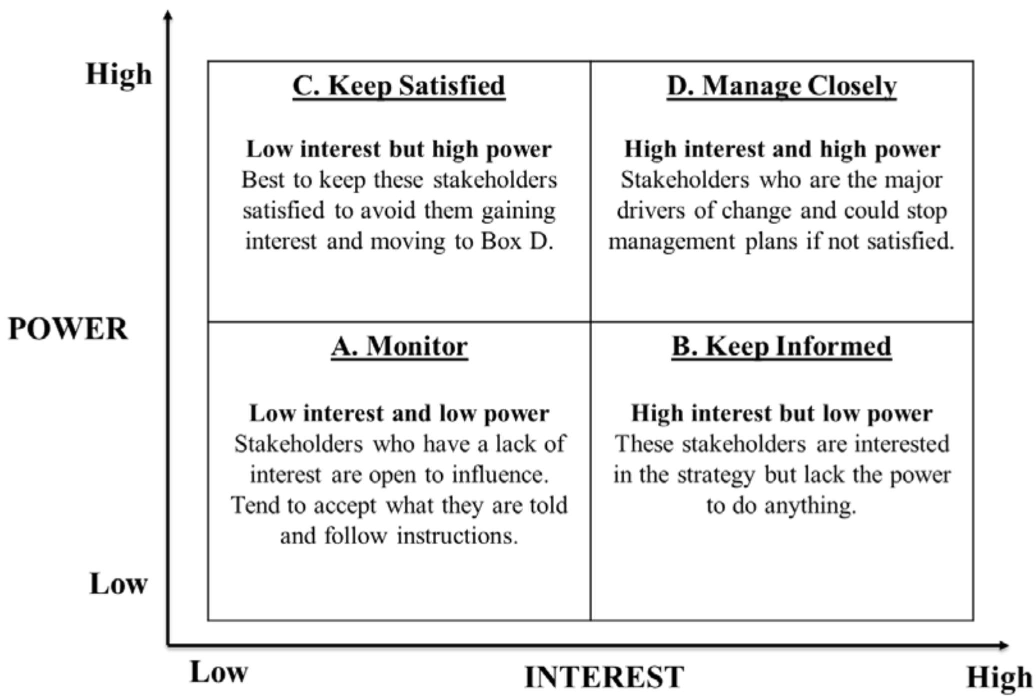

Figure 7. Power-Interest Matrix. Source: Mendelow (1991).

(4) Determine Key System Stakeholders

Langford defined the key system stakeholders as those who are responsible for the acquisition, development, and integration of the TTT. Hence, the key system stakeholders must be involved as early as the initial stage of TTT development so as to see the TTT through the acquisition, development, and integration stages. Alternatively, the key stakeholders can also be defined based on the frequency of direct interactions with other stakeholders within the system. Stakeholders with more interactions are likely to influence the system to a large extent.

(5) Define Stakeholders' Requirements

Defining the stakeholder requirements is one of the most important steps during the initial stage of the SE process. The inputs and requirements solicited from the key stakeholders are used to derive top-level technical requirements for the TTT that in turn serve to address the operational requirements (true need) in a naval facility (DAU n.d.). Using the mnemonic acronym S.M.A.R.T, developed by George T. Doran (1981), in setting the requirement is a useful way to start. A brief description of each attribute follows:

- **Specific:** The requirement must be clear, concise, and as simple as possible. The wording of requirement must be able to achieve the same interpretation across different stakeholders.

- **Measureable:** The requirement must be able to be measured qualitatively and quantitatively.

- **Assignable/Attainable:** The requirement must be achievable given the circumstances in which the system will be used.

- **Realistic:** The requirement must be associated with real-life performance measurements.

- **Time-bound:** The requirement must include time-based elements to ensure it is traceable and progressively monitored.

Identifying the key stakeholders and getting their advice in developing new TTTs is pivotal to increasing the likelihood of successful technology integration. This is because the key stakeholders are able to articulate their needs in detail and ensure that the developed TTT truly meets its intended purpose. Upon the completion of a new TTT, the key stakeholders will also have vested interests in implementing the TTT at their respective naval facilities and getting their end users to adopt it.

2. Comparative Analysis of NESDI's Integration Process Versus the Adoption and Diffusion (Innovation-Decision) Process

The second comparative analysis is conducted between the current NESDI integration process and the adoption and diffusion process (see the shaded region of Figure 8). The adoption and diffusion process is adapted from the innovation-decision model developed by Rogers (1995) to capture the behavior of individuals on how they would respond to new TTT. This comparison aims to assess the effectiveness of technology integration at naval facilities based on how the TTT is communicated and "advertised" to the end user. These processes are followed closely to draw comparisons with NESDI *Project 288* (Nofoam system for automotive fire apparatus vehicle foam discharge checks, or Nofoam unit technology, for short) in Chapter IV of this study.

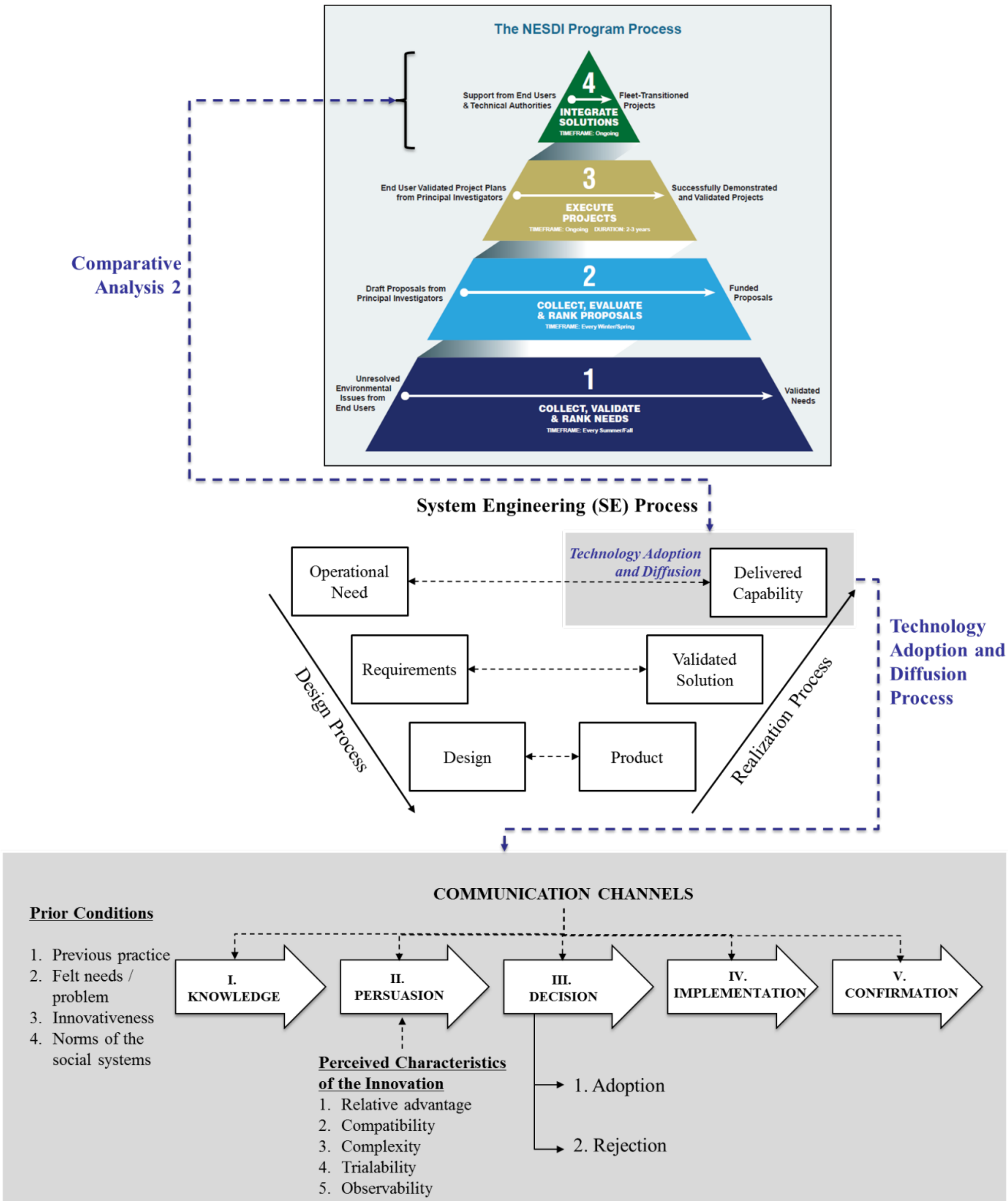

Figure 8. Comparative Analysis of NESDI's Integration Process and the Adoption and Diffusion Process. Adapted from NESDI (2016).

a. Technology Adoption and Diffusion Process

Technology adoption at the organization level (targeted naval facility) and technology diffusion at the enterprise level (two or more naval facilities) are both desired outcomes of the NESDI program. To achieve this, understanding the behavior of end users with respect to accepting a new TTT can help the NESDI technology integration team to tailor a communicate plan to suit different naval facilities.

The technology adoption and diffusion process, also known as the innovation decision model conceptualized by Rogers (1995) begins with the end user when he or she is (1) aware of the new TTT (knowledge), (2) forms an attitude toward the TTT (persuasion), (3) decides whether to incorporate the new TTT into ongoing practice (decision), (4) uses the TTT (implementation), and (5) recognizes the benefits of using the TTT (confirmation) (see Figure 9). As the process takes time, a carefully orchestrated communication plan is essential to introduce the new TTT to a naval facility. The basis of the second comparative analysis centers on this process to draw a comparison with NESDI *Project 288*.

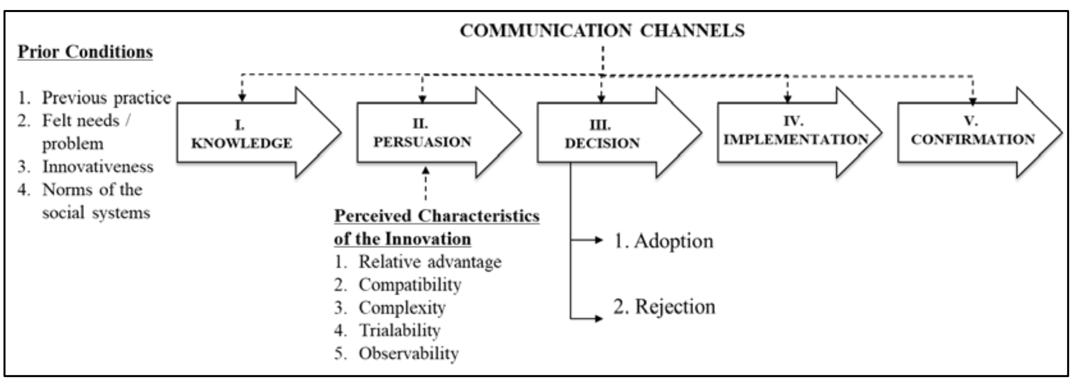

Figure 9. Innovation-Decision Model. Source: Rogers (1995).

(1) Stage I: Knowledge

Suppose the TTT is at the final phase of development (or at any phase the stakeholders deem suitable) before rolling out for facility-wide implementation, the key stakeholders who are involved in the TTT development must begin to create awareness within the naval facility to inform employees (who are also the end users) about the new TTT. Prior to this, a comprehensive and deliberate transition plan to assimilate the new TTT into the naval facility must be established and address how the new TTT will be rolled out and how the end users will begin using it or how the work process will change to use the new TTT. Training, maintenance, and relevant plans required for the new TTT must also be established as part of the TTT development process. With this, the end users will have confidence in adopting the new TTT.

(2) Stage II: Persuasion

Stakeholders from the naval facility who are involved in the development of new TTT are responsible for getting their end users to adopt the new TTT. On one hand, getting them to use the new TTT requires command emphasis driven by the base commander of the naval facility. On the other hand, there is also a need to persuade the individual or group of individuals to form a favorable attitude toward the new TTT. At this stage, when individuals become aware of the new TTT, they will start looking out for more information, which gradually leads them to form either an unfavorable or favorable attitude toward the new TTT. To provide a holistic understanding of how individuals would react, Rogers highlighted five perceived characteristics of behavior (see Table 2). Understanding the five perceived characteristics of behavior can help the stakeholders to design and tailor an effective communication plan for the new TTT (Rogers 1995).

Table 2. Perceived Behavioral Characteristics and Communication Plan.

Perceived Characteristic	Description	Communication Plan
Relative advantage	The extent to which an individual views a new TTT as a better option than the existing one.	To clearly state the benefits (for the individual) of using the new TTT.
Compatibility	The extent to which how an individual's may use his/her existing experience to operate the new TTT.	To clearly state how existing experience and work processes may be applied to the new TTT.
Complexity	The extent to which the new TTT is easy for the	To clearly state the means available (i.e., through a briefing or training) for the

Perceived Characteristic	Description	Communication Plan
	individual to understand and learn.	individual to learn about the new TTT.
Trialability	The extent to which the TTT can be trialed. With more end users exposed to the new TTT during the trialing stage, the probability of TTT adoption when it is implemented will be high.	To clearly state when and how the new TTT will be trialed; and to invite as many team leads to attend as possible.
Observability	The extent to which potential end users are aware of this TTT and its benefits.	To be determined by how the stakeholders would want to advertise in the naval facility.

(3) Stage III: Decision

At this stage, after the individual has formed an opinion about the TTT, he or she may decide whether to adopt the new TTT. Since the TTTs developed by the NESDI's program are mainly for the Navy, command emphasis must be enforced to use the new TTT. Hence, at the decision stage, the end users are expected to accept the new TTT. It is, however, important to establish a channel of feedback for the end users so as to further improve the TTT.

(4) Stage IV: Implementation

Implementation happens when individuals put the new TTT into use. This stage is potentially where operations may be disrupted by end users who are unfamiliar with the TTT or who are not informed about the change. Hence, it is important that all related end users are aware of the new TTT at the knowledge stage of the innovation-decision process to prevent any confusion. Rogers (1995) points out that this stage usually lasts for a long time, depending on the nature and type of TTT, before normalizing.

(5) Stage V: Confirmation

Once the TTT has successfully been assimilated as part of the work process in place of the previous TTT, the new TTT can be considered as adopted. Therefore, the new TTT is said to have transitioned at this stage when the end users recognize the benefits of using the new TTT.

D. DEVELOP FRAMEWORKS FOR THE NESDI PROGRAM

The final step of the methodology is to summarize the findings from the comparative analyses conducted between the SE and diffusion processes and the process NESDI adopted for their projects. The findings will be used to establish two frameworks for the NESDI program. The frameworks can serve as guidance for NAVFAC and the NESDI program to align and develop future TTTs and increase the likelihood of successful technology integration.

IV. COMPARATIVE ANALYSIS OF INTEGRATION PROCESSES

A. OVERVIEW

This chapter analyzes and evaluates the processes undertaken by the NESDI program to identify the shortfalls in technology integration. Further, the chapter proposes appropriate frameworks to achieve increased likelihood of technology integration.

B. INITIAL ASSESSMENT OF NESDI'S PROCESSES

To assess the effectiveness of technology integration within NESDI's program, the NESDI standard operating procedures (SOP) document is evaluated first. Based on the interactions with the program manager, technology integration team lead, and principal investigators during the author's site visit in April 2018, an initial assessment and a suggested course of action were developed. They are highlighted here to evaluate the 15 conditions of technology integration that the NESDI program seeks to achieve when implementing new TTT at a naval facility (NAVFAC 2010). The initial assessment provides a generalization covering most NESDI TTT projects and it reveals that needs and stakeholder analyses might be the underlying reasons why the technology integration at naval facilities is challenging and often unsuccessful (see Table 3).

Table 3. Assessment of NESDI's Processes.

Conditions for Successful Integration Stated in NESDI SOP (NAVFAC 2010)		Initial Assessment	Suggested Course of Action
1.	The user community has validated the technology.	TTT developed based on perceived need, not true need as the key stakeholders of the TTT are not identified and involved in the development. Thus, validation of TTT by the user community might not be relevant and accurate.	Problem definition needs analysis and stakeholder analysis should be conducted at the beginning to identify the true need and key stakeholders to develop the TTT according to the stakeholders' requirement.
2.	Funding has been planned for and is in place for transition.	Project budget allocated for a particular TTT is usually insufficient to cover both development and integration costs. Therefore, funding for	Stakeholder analysis should be conducted at the beginning to identify the key stakeholders. Key stakeholders are likely to fund the project if the TTT is

Conditions for Successful Integration Stated in NESDI SOP (NAVFAC 2010)		Initial Assessment	Suggested Course of Action
		technology integration is mostly from the naval facility interested in the TTT.	developed according to their needs and requirements.
3.	The stakeholders have accepted the technology.	The stakeholders identified by the NESDI program did not adopt most of the newly developed TTT. They might not have regarded the TTT as a true need.	Key stakeholders should be identified at the beginning and be involved throughout the TTT development so that the TTT developed meets their specific need.
4.	A marketing strategy is in place.	Efforts to market the TTT typically start only when the TTT is developed and validated. Validated results and benefits were then advertised to seek interested parties. Even so, there is often little or no interest.	Stakeholder analysis should be conducted at the beginning to identify the key stakeholders and to involve them in the TTT development from the start. They should be facilitating the technology integration at their respective sites.
5.	An implementation plan and schedule are in place.	Most projects did not reach this stage.	-
6.	Customer satisfaction has been assessed and documented.	Most projects did not reach this stage.	-
7.	The support infrastructure (Integrated Logistics Support) is in place.	Most projects did not reach this stage.	-
8.	A training plan has been developed and fleet personnel have been trained. The use of the technology has been implemented.	Most projects did not reach this stage.	-
9.	An acquisition agent has been identified and funding secured.	Most projects did not reach this stage.	-
10.	Commercialization is available (if no acquisition agent exists).	TTT were advertised with fact sheets and technical data but gained little or no interest.	Stakeholder analysis should be conducted at the beginning to identify the key stakeholders. Key stakeholders are likely to adopt the TTT if it is developed according to their needs and requirements.
11.	The System Commands and the Fleet recognize a formal change in their business processes to accept the new technology.	Most projects did not reach this stage.	-

Conditions for Successful Integration Stated in NESDI SOP (NAVFAC 2010)		Initial Assessment	Suggested Course of Action
12.	The former technology has been replaced or eliminated.	Most projects did not reach this stage.	-
13.	Benefit metrics have been reassessed and validated.	Most projects did not reach this stage.	-
14.	The use of the technology has been implemented.	Most projects did not reach this stage.	-
15.	The technology has been made available through the supply/procurement system	Yes.	-

C. COMPARATIVE ANALYSIS OF NESDI'S DEVELOPMENT PROCESS AND THE SYSTEMS ENGINEERING PROCESS

The initial assessment of NESDI's process in Table 3 indicates that the NESDI's TTT development process may not have included the process of identifying an effective or true need, along with relevant key stakeholders. As a result, most of the conditions established for technology integration as stated in the NESDI SOP are not satisfied. For any TTTs to achieve successful technology integration, the foundation for the development must first be established. To do so, the SE process advocates the conduct of (1) detailed problem definition, (2) needs analysis, and (3) stakeholder analysis during the initial development phase. The key to determining the effective need is by revising the problem statement iteratively whenever there is new information, knowledge, and stakeholder inputs (see Figure 10). Conducting the three key processes effectively sets the foundation and forms the basis to facilitate the subsequent development process.

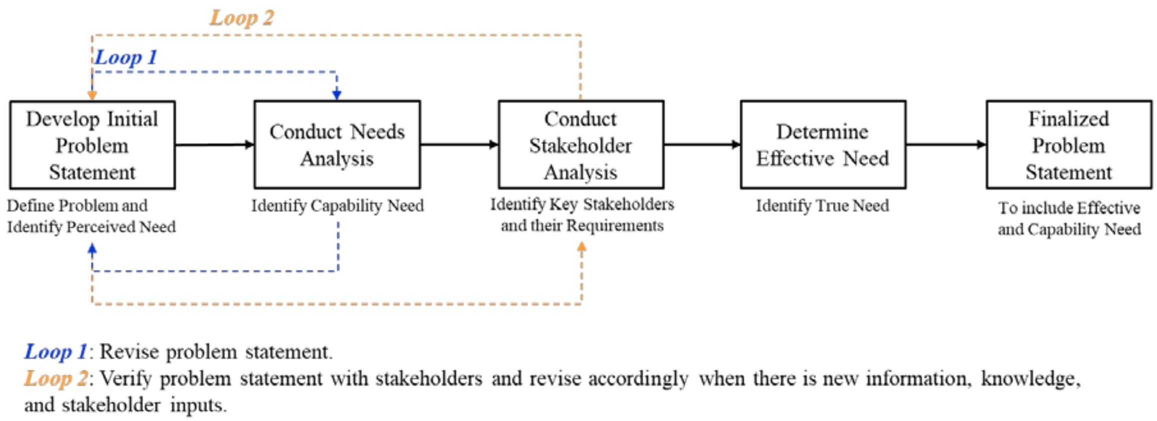

Figure 10. SE Initial Development Process.

To verify the results from the initial assessment, the development process for *Project 341* (zinc removal from compensating ballast water) is selected to compare with the problem definition, needs analysis, and stakeholder analysis in the SE process. Since *Project 341*'s completion in 2006, only one site has adopted this TTT. This is undesirable as NAVFAC and the NESDI program aim to integrate all TTT they developed to as many sites as possible. Like *Project 341*, NAVFAC/NESDI share similarities with many other completed projects that have achieved little or no technology integration at naval facilities. Hence, we use *Project 341* to represent many of the NESDI projects that did not achieve the desired technology integration.

The approach for conducting a comparative analysis of the problem definition and needs analysis relies on a list of relevant questions designed to evaluate the clarity of the problem and the need identified based on the available documents for *Project 341*. Gaps identified between the development processes adopted for *Project 341* and the SE process explain why the zinc removal system is unable to be integrated into other naval facilities. The findings from the comparative analyses are then utilized to develop a framework that serves as guidance from which NAVFAC and the NESDI program can take alignment and develop future TTTs so as to increase the likelihood of successful technology integration.

1. Background of *Project 341*

The Navy's DD-963 SPRUANCE-class Destroyers, DDG-993 KIDD-class Guided Missile Destroyers, and the CG-47 TICONDEROGA-class Guided Missile Cruisers, are designed with water compensating fuel (WCF) systems. The WCF system allows the seawater to enter the fuel tank during refueling operations. Compensating ballast water, or compwater, refers to the seawater that enters the fuel tank and helps to maintain proper trim and ship stability. During refueling operations, the incoming fuel displaces the compwater, which is later discharged from the ship through overboard discharge ports. This poses an environmental risk because the compwater contains a small amount of fuel and other impurities. Before the oily waste can be removed from the compwater, it has to be treated. Because the cost of treating the compwater is very expensive (approximately $0.26 per gallon), the compwater collection and management (CCM) system was developed to provide a cost-effective and environmentally sound alternative to treat the compwater. Since then, the CCM system has been effectively treating the compwater. When the new Arleigh Burke destroyers arrived, however, they produced compwater containing a high concentration of zinc that the CCM cannot treat. To ensure that the CCM system can continue to treat the compwater produced by the Arleigh Burke destroyers effectively, zinc impurities must first be removed. Hence, *Project 341* was proposed as an add-on system for the CCM system at Naval Station (NAVSTA) Everett. The development of the zinc removal system involved the designing of the media/filtration unit that helps to remove the metals from the compwater.

2. Comparison 1: Conducting Problem Definition

Like any other problem-solving methodologies, crafting problem statements helps the problem solvers (in this case, principal investigators and stakeholders) to stay focused. The initial problem statement is crafted to capture the perceived need. To translate the perceived need to an effective or true need, the problem statement must be revised iteratively according to the SE process depicted in Figure 10. Based on the *Project 341* report (Kudo 2010), relevant but non-exhaustive questions are listed to evaluate whether the project's problem definition and problem statement are sound. From the evaluation (see

Table 4), it seems the lack of stakeholders from other ports may hinder the problem from rising to the enterprise level. NAVSTA Everett, where the new Arleigh Burke class destroyers were docked, was the only affected port named in the report. Although the problem may be valid locally to NAVSTA Everett, there is a need to identify other ports that are also experiencing the same problem. This would better support the view that problem exists at the enterprise or fleet level.

Table 4. Evaluation of *Project 341*'s Problem Definition.

Problem Definition Clarifications	***Project 341* Problem Definition**	**Remarks**
When did the problem arise?	When the newer Arleigh Burke class destroyers were introduced, the compwater they discharged contained a high concentration of zinc impurities.	-
What had been done to address the problem before?	None. This is considered a new problem as the compwater discharged by all other classes of destroyers at NAVSTA Everett contains acceptable limits of zinc impurities.	This is only based on the type of destroyers docking at NAVSTA Everett.
What would the world be like if the problem did not exist?	*Project 341* would not be required and the CCM could continue its operation of treating the compwater normally.	-

Problem Definition Clarifications	*Project 341* Problem Definition	Remarks
Do we have all the facts or supporting evidence? Are they accurate?	Based on the project documents, NAVSTA Everett is the only port mentioned where the Arleigh Burke class destroyers are docked. With that, the compwater produced by these destroyers is untreatable due to the zinc impurities.	May need more stakeholders (ports where similar destroyers are docked) to better support the problem definition.
Is there a logical explanation for the cause of the problem?	Yes, the higher concentration of zinc produced by the Arleigh Burke class destroyers is due to the increase in the sacrificial anodes for cathodic protection.	-
Does everyone think that it is a problem?	Based on the project documents, only NAVSTA Everett is cited to experience this problem, as it is the homeport for the new class of destroyers.	May need more stakeholders (ports where similar destroyers are docked) to better support the problem definition.
Who or what is impacted?	NAVSTA Everett is impacted as the current CCM system is incapable of treating compwater with zinc impurities.	-
What is the environment and what are the external factors that affect the problem?	Regulatory guidelines that restrict the discharge of compwater that contains zinc impurities exceeding 4 parts-per-million (ppm).	-

3. Comparison 2: Conducting Needs Analysis

Once the problem is adequately defined, the next step is to identify the capability need that the technology is intended to fill. Identifying the capability need would help to determine the effective need. The problem definition of *Project 341* states that the CCM system at NAVSTA Everett was incapable of removing zinc impurities from the compwater. Therefore, the removal of zinc is considered to be a capability need of NAVSTA Everett. Since no other NAVSTA was named or identified in the project report, there is insufficient evidence to support the zinc removal system as an enterprise-level need. This could be the reason why other NAVSTA are not keen to adopt this technology. Based on the *Project 341* report, relevant but non-exhaustive questions are listed to evaluate whether the need identified is sound (see Table 5). The evaluation shows that the need to remove zinc impurities from the compwater is unique to NAVSTA Everett while the report cited the possibility that other NAVSTA might need this technology due to the increased number of Arleigh Burke class destroyers being built. Hence, the zinc removal capability can be regarded as a localized need for NAVSTA Everett. For the zinc removal system to be integrated beyond NAVSTA Everett, it has to be an enterprise-level need.

Table 5. Evaluation of *Project 341*'s Needs Analysis.

Need Analysis Clarifications	***Project 341* Needs Identification**	**Remarks**
What is the situation? Is it a new development or an improvement type of project?	A zinc removal system was developed as an add-on system for the CCM.	-
What kind of need is the system/TTT fulfilling?	The need to remove zinc impurities from the compwater produced from the Arleigh Burke class destroyers during refueling operations.	This need is unique to Arleigh Burke class destroyers during refueling operations.
Is there any relationship with other needs?	Yes, the zinc removal system has to be employed with the CCM to collectively treat the compwater produced by the Arleigh Burke class destroyers.	The zinc removal system is only required at NAVSTA where Arleigh Burke class destroyers dock.
What is the frequency of the need?	Dependent on the operations of Arleigh Burke destroyers.	-
How urgent is the need?	It was considered to be an urgent need for NAVSTA Everett as the compwater produced by the Arleigh Burke class destroyers cannot be effectively treated by the CCM alone.	-
What limits are imposed on the solution set?	The aim is to reduce the zinc impurities to below the sewer discharge limit of 4 ppm.	-
Are there tolerances to be observed when satisfying the need?		

Need Analysis Clarifications	*Project 341* Needs Identification	Remarks
What are the potential impacts on the environment and on other systems?	Discharging untreated compwater may cause adverse environmental effect.	-
What are the viewpoints of the stakeholders?	NAVSTA Everett requested a solution to remove zinc in compwater and provided funding of $20,000 to the Naval Facilities Engineering Service Center (NFESC) – a predecessor organization of NAVFAC – to evaluate the zinc removal technology for their CCM.	NAVSTA Everett is the only stakeholder involved during the development of the zinc removal system.

4. Comparison 3: Conducting Stakeholder Analysis

From the previous analyses conducted on the *Project 341* problem definition and needs analysis, NAVSTA Everett could be the only stakeholder engaged for the project development. As such, NAVSTA Everett is regarded as the key stakeholder for *Project 341* because the refueling operation for the Arleigh Burke class destroyers at its port is dependent on the zinc removal system. Without it, the CCM cannot process the compwater with zinc impurities. For the zinc removal system to be adopted fleet-wide and at the enterprise level, more key stakeholders from various NAVSTA must be identified. Since *Project 341* only identified NAVSTA Everett as the stakeholder, the following process illustrates an example of how a larger number of relevant key stakeholders may be identified as part of the SE process.

a. Identifying Potential Stakeholders

The identifying of key stakeholders begins with shortlisting all potential stakeholders who face the same problem. To identify them for *Project 341*, two criteria are established in selecting the potential stakeholders. First, ports subjected to the same regulations and standards on the treatment of compwater (i.e., zinc impurities in the compwater must be less than 4 ppm) should be considered as potential stakeholders. This is because not all ports may have the same governing standards, and thus, the zinc removal system might not be applicable. Second, since *Project 341* mainly targets the Arleigh Burke class destroyers, which produce compwater with a high concentration of zinc impurities, all ports that receive the Arleigh Burke class destroyers for refueling operations should also be considered as the potential stakeholders since treating the compwater will be an essential operation. The public works department (PWD) can also be considered as a potential stakeholder because it is responsible to collect and treat the compwater at the refueling ports. With the aforementioned considerations, we can now identify at least three potential stakeholders, along with their corresponding roles, as stated in Table 6. Stakeholders who are considered to have a key role in the development of a specific TTT should be included in this process of identifying potential stakeholders.

Table 6. Identification of Potential Stakeholders and Their Roles.

Stakeholders	Key Appointment Holders	Description of Role / Appointment with Respect to Project 341
Homeports	Commanding Officer	To ensure that relating doctrine, organization, training, materiel, leadership and education, personnel, and facilities (DOTMLPF) for the zinc removal system are in place and the implementation of the new system does not impact or cause disruption to other services within the homeport.
	Naval Environmental Officer	To ensure that relevant regulations established by the Environmental Protection Agency (EPA) and other governing standards for all supporting services in the homeports are satisfied.
Refueling Ports	Commanding Officer	To ensure that relating DOTMLPF for the zinc removal system are in place and the implementation of the new system does not impact or cause disruption to other services within the port.
	Naval Environmental Officer	To ensure that relevant regulations established by the EPA and other governing standards for refueling operations are satisfied.
Public Works Department (PWD)	Department Head	To collect compwater discharged by the Arleigh Burke class destroyers during refueling and treat it in accordance to specified standards.

b. Classify Potential Stakeholders

Once the potential stakeholders from the various NAVSTA are identified, the next step is to classify them into (1) internal, (2) first-order, and (3) second-order stakeholders. First, the internal stakeholders for *Project 341* can be regarded as the NAVSTA, which are homeports to the Arleigh Burke class destroyers. Homeports provide all forms of services to all types of naval ships that are assigned there. Services include the refueling operation where treating the compwater is essential. Next, the first- and second-order stakeholders can be classified according to the frequency of visits to a particular port for refueling. A port with a higher frequency of visits by the Arleigh Burke class destroyers over a defined duration should be regarded as a first-order stakeholder.

The case for the PWD is rather unique. Currently, collection of compwater for treatment during refueling is not mandatory. Hence, the collection and treatment of compwater is only done at some refueling ports. As the job of collecting and treating the compwater is carried out by the PWD, the Arleigh Burke class destroyers, which dock at refueling ports, pay the PWD based on the quantity of compwater collected and treated. Therefore, being the "executor" of *Project 341* at selected refueling ports, PWD is regarded as a second-order stakeholder. Nevertheless, if the collection and treatment of compwater becomes mandatory at all refueling ports, PWD will certainly be raised to a first-order or even an internal stakeholder.

c. Determine the Stakeholders-System Relationship

This step entails the prioritization of all potential stakeholders according to how they may influence the development of the system. Using the Power-Interest Matrix, the stakeholders from homeports are considered to have greater power and interest in developing the zinc removal system as it is assumed that the zinc removal capability is an effective need. The stakeholders from the refueling ports and the PWD follow behind, as depicted in the Power-Interest Matrix (see Figure 11). In the actual evaluation of the stakeholders-system relationship, there is a need to confirm and verify all information to ensure that the prioritization of the stakeholders is accurate. An example of the notional stakeholders-system relationship for *Project 341* is depicted in Figure 11 and further elaborated in Table 7, along with how the identified stakeholders may affect technology integration.

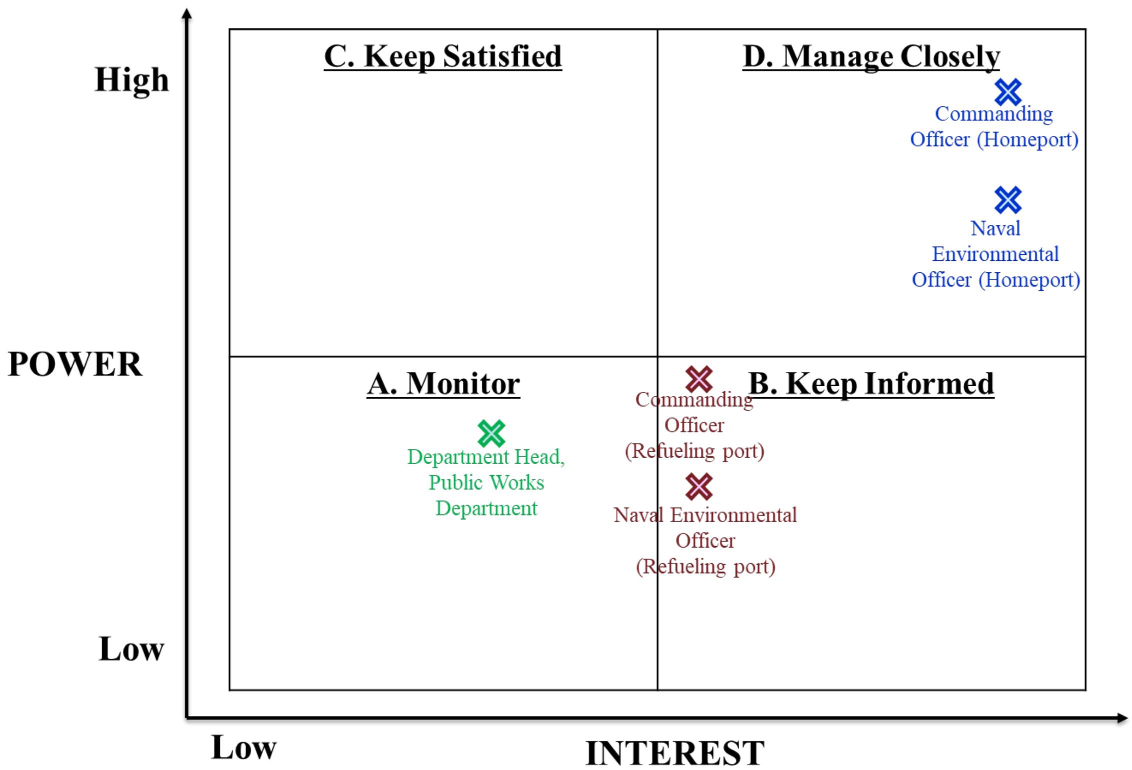

Figure 11. Power-Interest Matrix for *Project 341*.

Table 7. Stakeholders' Impact on Technology Integration.

Stakeholder	Department Head	Commanding Officer Naval Environmental Officer	Commanding Officer Naval Environmental Officer
Unit	Public Works Department	Refueling Port	Home Port
Power-Interest Quadrant	A. Monitor (Low Interest; Low Power)	B. Keep Informed (High Interest; Low Power)	D. Manage Closely (High Interest; High Power)
Impact to Technology Integration	Little to no impact.	Moderate impact.	Significant impact.
Suggested Course of Action	To keep stakeholder updated on project matters relevant to the stakeholder's interests and monitor if there is any sudden change of interest on issues relating to the TTT.	To keep stakeholder constantly informed of project progress and ensure there are no major issues.	To keep stakeholder satisfied as much as possible.
Remarks	Stakeholder may not have high interest and power as a second-order stakeholder, and are likely to be influenced by stakeholders with more power. However, if the collection and treatment of compwater becomes mandatory at all refueling ports, he/she may be shifted into quadrant D.	Stakeholders are very interested in project but may lack the power to make key decisions. However, they would still be keen to highlight potential areas for improvement aiming to maximize technology integration at their ports.	Stakeholders who make key decisions throughout the development of the project aim to maximize technology integration at their ports.

d. Determine Key System Stakeholders

The key system stakeholders for *Project 341* are the commanding officers of the bases (homeports and refueling ports). They are responsible for the acquisition, development, and integration of the zinc removal system at their respective bases.

e. Define Stakeholders' Requirements

The last step to stakeholder analysis is to define the stakeholders' requirements. By soliciting all inputs and requirements for the zinc removal system from the bases' commanding officers (key stakeholders), requirements statements can be crafted using the S.M.A.R.T. attributes to accurately reflect the stakeholders' requirements. These requirements statements will also be used to derive top-level technical requirements for the zinc removal system during the development phase. A sample list of requirements statements is illustrated in Table 8.

Table 8. Requirements Statements for *Project 341* (*For Illustration Purposes*).

Objectives	Requirements Statement
Minimize zinc impurities in compwater.	*"The zinc removal system shall effectively remove the zinc impurities from the compwater such that the zinc impurities measurement after treating the compwater does not exceed 4 ppm."*
Maximize the usage of the zinc filter media.	*"The filter media within the zinc removal system shall be replaced after treating at least 5 million gallons of treated compwater or when the zinc removal effectiveness is spent, whichever is longer."*

5. Gaps Identified from Comparative Analysis of NESDI Development Process and the SE Process

Three main gaps are identified from the preceding comparative analysis of the development process for *Project 341* and the SE process of problem definition, needs analysis, and stakeholder analysis (see Table 9). The gaps identified may be the reasons why technology integration for *Project 341* is challenging.

Table 9. Findings from *Project 341*.

SE Process	Gaps Identified between NESDI and SE Process
Problem Definition	An insufficient number of NAVSTA facing the same problem of treating compwater with a high concentration of zinc impurities was identified. Therefore, the lack of data does not substantiate the problem as an enterprise-wide problem.
Needs Analysis	The need is considered to be unique to Arleigh Burke class destroyers docking in NAVSTA Everett during refueling operations where the compwater produced by the destroyers contains high concentrations of zinc. Therefore, it is regarded as an effective need to them. Hence, there is a lack of data indicating whether other

SE Process	Gaps Identified between NESDI and SE Process
	ports are experiencing a similar need as NAVSTA Everett.
Stakeholder Analysis	There is a lack of stakeholders (i.e., other ports and homeports) to support the adoption of *Project 341* at potential sites.

6. Development of Framework 1

Using the gaps identified previously, the first framework is developed for NAVFAC and the NESDI program from which to take alignment in developing future TTTs. The framework is represented by an N-squared model where the steps of conducting problem definition, needs analysis, and stakeholder analysis are arranged in sequential order. As the conduct of each step of the process may be dependent on the preceding and succeeding steps, lines linking the relevant steps are plotted to establish the relationships. This framework is envisaged to provide NAVFAC and the NESDI program the foundation necessary to facilitate the development of the TTT and, more importantly, to increase the likelihood of successful technology integration fleet-wide and at the enterprise level.

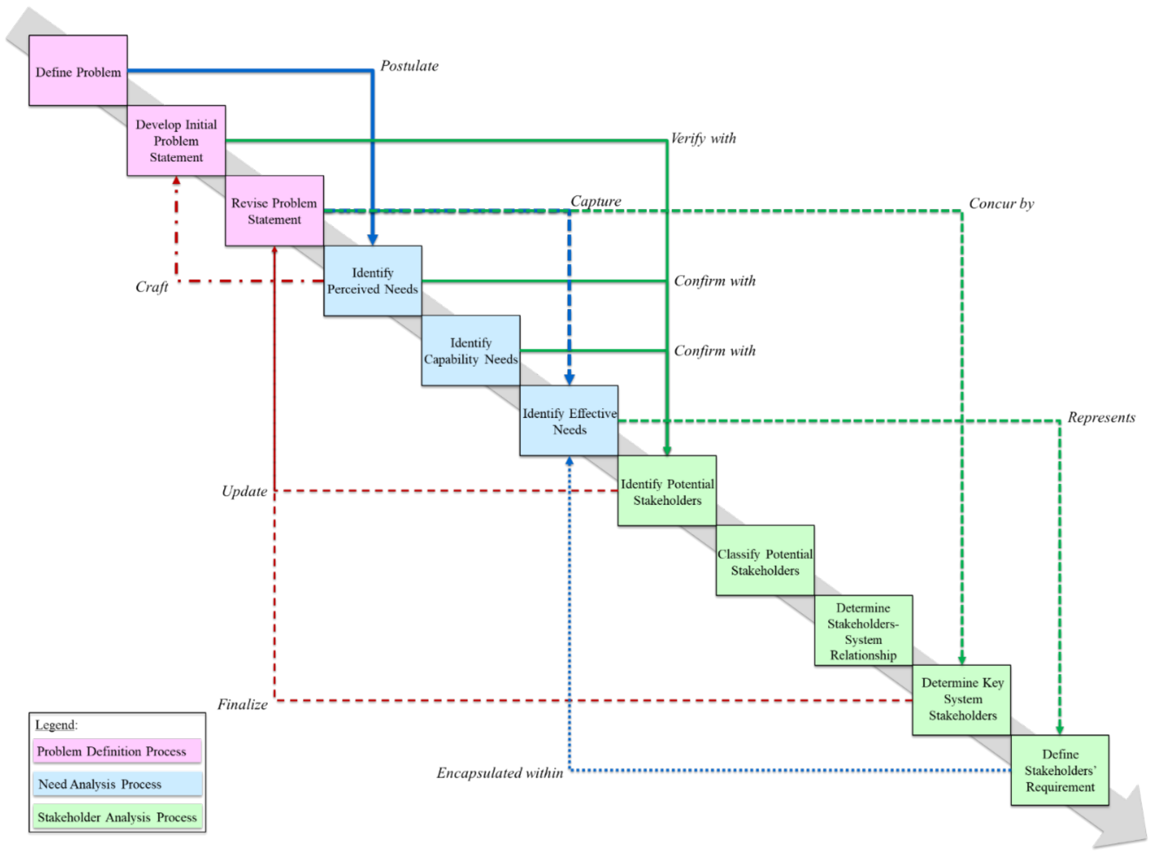

Figure 12. Framework for Comparative Analysis of NESDI's Development Process and the SE Process.

D. COMPARATIVE ANALYSIS OF NESDI'S INTEGRATION PROCESS AND THE ADOPTION AND DIFFUSION PROCESS

The initial assessment of NESDI's process in Table 3 shows that most projects did not achieve technology integration at the intended naval facility and at the enterprise level of the U.S. Navy. This is because the newly developed TTT did not reach the technology transition and adoption stage due to the apparently inadequate conduct of needs and stakeholder analyses. Hence, technology diffusion at the intended naval facility could not be realized. While Framework 1 addressed the necessary procedures to establish the foundation (i.e., conduct of problem definition, needs analysis, and stakeholder analysis) toward achieving technology integration, Framework 2 developed in this section provides a strategy to facilitate the integration of the TTT at naval facilities.

The Nofoam system for automotive fire apparatus vehicle foam discharge checks, or NESDI *Project 288,* is selected for the comparative analysis of the adoption and diffusion process (also known as the innovation-decision process developed by Rogers). This project is selected because it is one of the very few projects that achieved technology integration, with more than 200 automotive fire apparatus vehicles DoD-wide that have adopted this TTT for use (Gordon 2018). The reason for the project's success was mainly attributed to the project's licensed vendor's effort to work with the National Fire Protection Association (NFPA) governing board in updating the standards that permitted the use of such technology (Gordon 2018). Coupled with NESDI's marketing effort of cold-calling the various sites, providing demonstrations, trainings, and presenting at technical conferences, the TTT was able to gain stakeholders' awareness beyond the U.S. Navy, achieving a considerable success in diffusing the TTT to some 200 automotive fire apparatus vehicles. Had the standards remained unchanged and not permitted the use of the new TTT, *Project 288* would not have been successful. Therefore, *Project 288* is regarded as a unique achievement for the NESDI program, and a useful case for this thesis.

Leveraging its success of diffusing the technology beyond the U.S. Navy, this chapter provides a comparative analysis of *Project 288* and the innovation-decision process (Rogers 1995) for insight on how to improve the implementation of new TTT. Framework 2 is based on results from the comparative analysis to further increase the likelihood of successful technology integration.

1. Background of *Project 288*

The Aqueous Film Forming Foam (AFFF) is an effective chemical agent widely used by the U.S. Navy Fire and Emergency services to extinguish any fire breakouts that result from the flammable and combustible liquids carried onboard ships, on airfields, fuel farms, streets, and roadways. Hence, a large quantity of AFFF is procured for various types of firefighting vehicles. To ensure operational readiness of the firefighting troops and serviceability of the firefighting vehicles, the NFPA fire codes require all vehicles to undergo routine serviceability checks. This in turn generates a large quantity of AFFF wastewater in the process. Due to its toxicity, the AFFF is regarded as a hazardous waste by the Environmental Protection Agency (EPA) and releasing any AFFF wastewater discharge without proper cleanup can potentially impact the environment. Therefore, all AFFF wastewater discharged from trainings and serviceability checks must be captured and properly disposed of. It is estimated that 20 percent of the AFFF procured annually is used for firefighting training and serviceability checks (Kudo 2010). With the high cost associated with the AFFF wastewater cleanup, fire chiefs at some naval facilities find it difficult to conduct the necessary checks due to limited operational budgets (Kudo 2010). Hence, fire safety at these naval facilities is compromised.

To reduce and effectively control the use of AFFF without compromising the operational readiness, NESDI introduced the Nofoam unit technology for the automotive fire apparatus vehicles, using an alternative agent (water or dyed water) in place of AFFF, to conduct serviceability checks in accordance with the NFPA fire codes. The Nofoam unit technology is a self-contained and trailer-mounted unit that connects to the firefighting vehicles to allow operational service checks without generating AFFF wastewater. With this TTT, the naval facility is projected to save up to 1,800 gallons of AFFF wastewater discharge and $3,600 in disposal costs per vehicle annually. In addition, an estimated consumption of up to 25 gallons of AFFF concentrate, translating to $175 per vehicle annually, can also be saved using this TTT.

2. Comparison 1: Knowledge Stage

The innovation-decision model begins with the Knowledge stage (Rogers 1995). The central idea of this stage is to create awareness about the new TTT at naval facilities so as to expose the end users to the new technology and to allow them to have hands-on experience with it. In the case of *Project 288*, the Nofoam unit technology was introduced to the end users at a naval facility's fire and emergency services as part of the demonstration and validation stage of the current NESDI's development process. Three naval facilities, (1) Naval Air Station (NAS) Jacksonville, FL; (2) NAS Lemoore, CA; and (3) Whidbey Island, WA, were selected to host the demonstration of the Nofoam unit technology. While the end users at these sites got first-hand experience on the new Nofoam unit technology, the rest of the sites were later informed through NESDI's advertising channel using fact sheets, a variety of print media (such as quarterly newsletters and *Current* articles, the U.S. Navy's energy and environmental magazine) and online publications (including the NESDI website and intranet). Marketing means such as cold-calling listed sites, providing demonstrations at requested sites, and presenting at technical conferences were also carried out to increase awareness about the TTT.

3. Comparison 2: Persuasion Stage

The second stage of the innovation-decision model is the Persuasion stage. This stage entails a two-fold approach to "persuade" the end users to try the new TTT. First, the implementation of the new TTT at a naval facility must be driven through command emphasis. Second, a suitable communication plan should be tailored to address the five perceived characteristics (see Table 10) corresponding to how one would react when introduced to new TTT. The perceived characteristics, also known as the end users' perceptions, may affect the rate of technology adoption (Rogers 1995). In the case of *Project 288*, the Nofoam unit technology mainly employs the same SOP when conducting routine checks on the vehicles required by the NFPA fire codes. Therefore, "persuading" the end users to adopt the TTT is much more straightforward than other stages since it requires minimal user training for operation and maintenance.

A tailored communication plan for each naval facility is a useful instrument that can support successful TTT integration. Table 10 illustrates a sample communication plan based on the five perceived characteristics to facilitate the implementation of the Nofoam unit technology. It can also serve as a reference to tailor a communication plan for TTT development in the future.

Table 10. Tailored Communication Plan (Sample) Based on Perceived Characteristics.

Perceived Characteristic	**Communication Plan**	**Sample Communication Plan for *Project 288***
Relative advantage	NESDI to End users	Requires additional step of connecting the trailer-mounted Nofoam unit technology to the fire apparatus vehicle for training and serviceability checks. End users, however, do not need to collect and clean up any wastewater produced during training and serviceability as the AFFF is now replaced by water / dyed water.
Compatibility	NESDI to End users	Requires no change in executing the SOP during training and performing routine checks. Existing experience on operating the fire apparatus vehicle is directly transferable as the Nofoam unit technology is a trailer-mounted container that connects to the vehicle.
Complexity	NESDI to End users	Requires minimal user training to operate and maintain the Nofoam unit technology.
Trialability	NESDI to Interested Stakeholders (after TTT is developed)	The Nofoam unit technology has been demonstrated at NAS Jacksonville, FL; NAS Lemoore, CA; and Whidbey Island, WA. Data recorded from the demonstrations validates the envisaged performance of the TTT. Stakeholders who are interested in this TTT may request for a copy of the technical report.
Observability	NESDI to Key Stakeholders for Project 288	Stakeholders involved in the development of the Nofoam unit technology are recommended to gather their end users during the demonstration by the licensed vendor. Alternatively, detailed presentations can be given at technical conferences to seek interested stakeholders.

4. Comparison 3: Decision Stage

The third stage of the innovation decision model is the Decision stage. Rogers (1995) opined that once the end user has formed a certain opinion about the TTT, the user has the choice to either adopt or reject the use of the TTT. While the TTT in this case is not designed to be sold to the general public, where individuals are able to choose whether they want to use / purchase or not (i.e., “As seen on TV” products), the TTT developed by NESDI seeks to address effective needs within the enterprise. These are also the needs that aim to help the U.S. Navy save costs and improve efficiencies. Therefore, strong command emphasis must be enforced top-down to ensure technology transition and adoption happens at naval facilities. With regard to *Project 288*, strong command emphasis and support from the fire chiefs at the three NAS were highlighted after the Nofoam unit technology was demonstrated on site (Kudo 2010). This resulted in a complete and successful testing of the Nofoam unit technology that supported and validated the benefits of the TTT. Likewise, key stakeholders identified at the start of project development should render such command emphasis and support in getting their end users to familiarize themselves with the use of new TTTs. Feedback channels should also be established at this stage as a means for end users to “feel the ground” and address potential concerns that may have been overlooked by the development team.

5. Comparison 4: Implementation Stage

The fourth stage of the innovation-decision model is the Implementation stage. Implementation of the TTT only happens when the end users put the TTT into actual use (Rogers 1995). This stage can be considered to occur together with the Decision stage since the use of the TTTs developed by NESDI should to be driven through command emphasis. In terms of the implementation of the Nofoam unit technology, there is no change to the SOP as the end users only need to connect the trailer-mounted unit that contains water or dyed water to the fire apparatus vehicle. Hence, implementation of *Project 288* was easily carried out.

6. Comparison 5: Confirmation Stage

The last stage of the innovation decision model is the Confirmation stage. End users at this stage would recognize the benefits that the new TTT brings. TTTs that reach this stage can be regarded as fully transitioned and adopted. Therefore, the next objective is to achieve technology diffusion across and beyond the U.S. Navy. The Nofoam unit technology has been able to gain such success by having more than 200 automotive fire apparatus vehicles adopt it DoD-wide. This was largely due to the effort of updating the standards and codes that permitted the use of the Nofoam unit technology as a bypass system in routine testing (Gordon 2018). This allows the TTT to be extended to other bases and sites beyond the U.S. Navy that are subjected to the same standards and codes. It must be noted, though, requesting that existing regulations be updated to suit an enterprise need is a challenging task that seldom succeeds. Hence, *Project 288* is considered as a unique case that achieved technology diffusion.

7. Findings from the Comparative Analysis of NESDI's Integration Process and the Innovation-Decision Process

The following findings are identified from the preceding comparative analysis between *Project 288* and the innovation-decision process (see Table 11).

Table 11. Findings from *Project 288.*

Innovation-Decision Process	**Findings from the Comparative Analysis of NESDI's Integration Process and the Innovation-Decision Process**
Knowledge stage	NESDI employed a series of advertising and marketing methods to increase awareness for *Project 288* only toward the end of the development phase. It should, however, be done at the start of project development according to the SE process. Conducting stakeholder analysis (as part of Framework 1) can help to create the initial awareness. The purpose of the initial awareness is to obtain stakeholders' support in developing the TTT. As the TTT has an increased likelihood being adopted by key stakeholders, credibility gained can further aid the TTT to circulate within and even beyond the enterprise.
Persuasion stage	To ensure end users use the new TTT in place of the current TTT, top-down command emphasis and an effective communication plan that addresses the five perceived characteristics should be carried out.
Decision stage	As in the Persuasion stage, command emphasis to use the TTT is encouraged. In addition, a feedback channel should be included to allow the end users to voice any concerns and suggestions for the new TTT.
Implementation stage	As in the Knowledge stage, command emphasis during implementation of the TTT is encouraged.
Confirmation stage	End users adopt the TTT.

8. Development of Framework 2

From the aforementioned findings, a second framework is developed from which NAVFAC and the NESDI program can take alignment in developing future TTTs. The framework is represented by an N-squared model where the five stages of perceived characteristics are arranged in sequential order (yellow boxes). The application of Framework 2 must be supported by Framework 1, as the latter lays the groundwork based on the SE process of identifying the effective needs and key stakeholders. With that, the innovation-decision process can be executed to further improve the likelihood of successful technology integration.

To increase awareness about the TTT at the Knowledge stage, it is recommended the key stakeholders identified from Framework 1 create an initial awareness among their end users at the start of the development phase. This is to solicit useful end user inputs for the development of the TTT. Upon the completion of the TTT, marketing strategies can be applied to advertise the TTT to other potential stakeholders who were not involved in the development of the project but are interested in the TTT.

To facilitate the adoption of the TTT at a naval facility, command emphasis is necessary at the Persuasion, Decision, and Implementation stages. This is to ensure that the benefits from the new TTT can be reaped in the shortest possible time. In addition, a communication plan should be developed at the Persuasion stage based on the five perceived characteristics to keep the end users informed about the new TTTs, so as to prepare them to accept the TTT at the Decision stage. At the Decision stage, it is recommended that a feedback channel be established for end users to voice any potential concerns that may have been overlooked by the development team (see Figure 13).

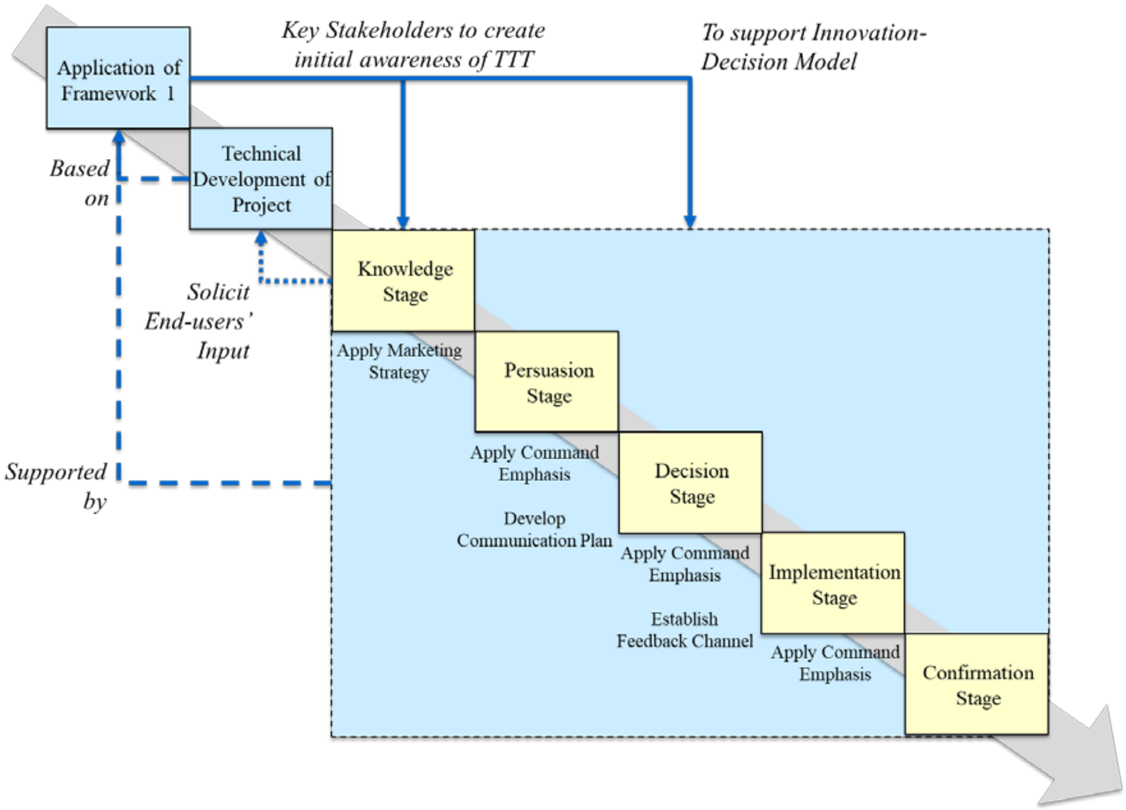

Figure 13. Framework for Comparative Analysis of NESDI's Integration Process and the Innovation-Decision Process.

V. CONCLUSION

A. CONCLUSION

The comparative analysis of integration processes examined in this study answers the following research questions introduced in Chapter I.

1. How do the current NAVFAC and NESDI integration processes compare to the Systems Engineering (SE) integration process?

The current NAVFAC and NEDSI integration processes depend on the demonstrated and validated results of the TTT at hosted sites before advertising and promoting it to potential adopters of the TTT. While the technical data from the demonstration may serve to support the usefulness and effectiveness of the TTT, the TTT might not have been developed according to stakeholders' needs and requirements. Therefore, it is challenging to integrate the new TTT into naval facilities. The SE integration process, on the other hand, focuses on the stakeholders' needs and requirements upfront, ensuring that the TTT developed not only gains the support of key stakeholders during the developmental stage, but also at the implementation stage.

To increase the likelihood of successful technology integration for NESDI, the meaning of "Integration" is redefined in Chapter 1 to include the process of technology transition, adoption, and diffusion. This newly defined integration for NESDI is then translated to Framework 1, where the SE approach of conducting problem definition, needs analysis, and stakeholder analysis are conducted to identify the effective needs and key stakeholders at the start of project development. With this, the stakeholders for the TTT will provide greater support to the development process as their effective needs are being addressed. Furthermore, Framework 2, developed from Rogers' innovation-decision model, aims to facilitate the TTT's transition and adoption at naval facilities, as it complements Framework 1 in achieving an even higher probability of successful technology integration.

2. How do NAVFAC and NESDI define integration and successful integration?

According to NESDI's SOP, 15 conditions are necessary for TTT to be successfully integrated at a naval facility (NAVFAC 2010). As part of the initial assessment in Chapter IV (see Table 3), it was evident that most of the conditions have not been achieved. This could be attributed to a lack of clarity in terms of identifying the effective needs and key stakeholders needed to support the technology integration. As the conduct of needs and stakeholder analyses is essential to support the technology integration at any naval facility, Framework 1 is proposed to first establish the foundation and pave the way for an increased likelihood of successful technology integration.

3. What are the challenges that NESDI encounters during the integration of a new TTT?

There are three main challenges that NESDI encounters during the integration of any new TTT. First, NESDI only markets the TTT when it has successfully been demonstrated at a host site. While the technical data from the demonstration may serve to support the usefulness and effectiveness of the TTT, the TTT might not have been developed according to stakeholders' needs and requirements. Therefore, finding potential buyers and customers is difficult as they are not involved in the TTT's development.

Second, interaction with the key appointment holders during the site visit to NAVFAC EXWC in Port Hueneme in April 2018 revealed that the naval facilities may also have limited budget to spend on new TTT to replace their existing TTT. As the cost of implementing new TTT may also involve training, maintenance, installation, (and other support), buying any new TTT would mean that the naval facility would have to compromise spending in other areas. Therefore, most potential buyers and customers have little or no interest in getting any new TTT despite its benefits.

Third, there is a lack of manpower to assist in implementing the TTT at naval facilities. This is because a technology integration team would be formed only when project budget allows. More often than not, project budget is limited and, hence, insufficient to support a technology integration team for executing the integration plan on site.

With these challenges, the integration of newly developed TTTs among the end users is slow, and the actual integration of new technologies into naval facilities is extremely poor. As a result, most TTT projects have eventually been shelved. The frameworks proposed in this study aim to address these challenges by first identifying the key stakeholders and their effective needs. Involving them in project development not only gives them foresight about development progress but also the confidence that the TTT developed will address their effective needs, improving work efficiencies and reducing costs at the implemented sites.

4. What means do the NAVFAC and NESDI provide to the end users during the course of TTT integration (i.e., subject matter expert training, just-in-time training, on-site assistance, feedback)?

This question was raised due to the initial suspicion that insufficient training and support were rendered on site, resulting in a lack of technology integration. This is not true as the difficulty in integrating the new TTT into naval facilities was due to the lack of key stakeholder support for the developed TTT, which did not address their effective needs. As such, marketing the newly developed TTT based on the current NESDI development process is difficult, and the goal of technology adoption and diffusion in the U.S. Navy is unlikely to be accomplished.

- How can the current NAVFAC and NESDI integration processes be modified to increase the likelihood of success?

Framework 1 essentially modifies NESDI's initial process to "collect, validate, and rank needs" (U.S. Navy Energy, Environment and Climate Change n.d.-b) (see Figure 1) to the conduct of problem definition, needs analysis, and stakeholder analysis based on the systems engineering activities and interactions over a system's life cycle. The aim is to establish a firm foundation with key stakeholders' support to develop the TTT in accordance with the effective needs and requirements.

Framework 2 essentially modifies NESDI's final process to "integrate solutions" (U.S. Navy Energy, Environment and Climate Change n.d.-b) (see Figure 1) by applying the innovation-decision model (Rogers 1995) to create awareness, drive command emphasis, develop a communication plan, and establish a feedback channel in facilitating the integration of TTT.

B. RECOMMENDATIONS

This thesis makes two recommendations to utilize the two frameworks developed in this study effectively:

1. Apply the Developed Frameworks to Existing Projects

Depending on the current phase of the project, applying the developed frameworks to existing and ongoing projects is recommended to make just-in-time corrections, if possible. The aim is to minimize any gaps that correspond to those identified in this study and increase the likelihood of technology integration to the greatest extent possible (see Table 12).

Table 12. Recommendation for Just-in-Time Correction.

S/N	Current NESDI Process	Recommendation for Just-in-Time Correction
1.	Collect, validate, and rank needs	Apply Framework 1 and try to identify as many key stakeholders as possible to verify that the in-development TTT is an effective need. Otherwise, attempt to identify the effective need and evaluate if it is feasible to make any amendments to the TTT development.
2.	Collect, evaluate and rank proposals	
3.	Execute projects	
4.	Integrate solution	Apply Framework 2 to implement the TTT at naval facilities.

2. Weave Frameworks into "New Start" Project Phases

As the frameworks are particularly meant to apply to "new start" projects, it is recommended to weave the SE and innovation-decision processes into the "new start" program schedule defined in the NESDI SOP document (NAVFAC 2010) (see Table 13).

Table 13. Weave Frameworks into "New Start" Project Phases.

Phases (NAVFAC 2010)		Recommendation	Framework
1.	Announce Solicitation for Needs	Define problem and conduct needs analysis to determine effective needs before validating and ranking the needs.	As part of Framework 1
2.	Collect Needs		
3.	Validate and Rank Needs		
4.	Solicit for Pre-proposals	Conduct stakeholder analysis to determine key stakeholders before submitting full proposal.	As part of Framework 1
5.	Receive Pre-proposals		
6.	Evaluate and Rank Pre-proposals		
7.	Solicit for Full Proposals		
8.	Evaluate Full Proposals		
9.	Announce Program New Starts	Ensure key stakeholders are supportive of the project. Principal investigators and key stakeholders should develop an action plan with Framework 2 to establish some foresight as to how the TTT will be implemented on site. Changes can be made as project progresses.	As part of both frameworks
10.	Fund New Start Projects		

C. FUTURE RESEARCH

There are many research opportunities and two of which are proposed:

1. Conduct Comparative Analyses on Other Types of Completed Projects

As this study only utilized two completed shore-based projects (*Project 341* and *Project 288*) in its comparative analyses, completed projects from other shore-based TTTs or other types of TTTs can be conducted to provide more inferences. With additional comparative analyses, the frameworks can incorporate new lessons learned and be revised accordingly.

2. Evaluate Projects where the Frameworks Are Applied

To evaluate the degree of success achieved when the frameworks are applied, further studies can be proposed to measure how well the TTT has been transitioned, adopted, and diffused in the U.S. Navy. Results from this study can reinforce the usefulness of the frameworks and provide a “tangible” form of benefit in using the frameworks.

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